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NEW FORMULA FOR THE FLOW OF WATER IN OPEN CHANNELS.*

Contributed by Hon. WM. J. McALPINE.

During the study of the new formulæ of Humphreys, Abbot, Bazin and Gauckler, it was found necessary to reduce the different formulæ to the same basis, in order to facilitate the comparison, and as in each formula, which expresses the rapidity of water in canals, the value $\sqrt{RJ}$ (R being the hydraulic mean depth, and J the sine of the slope of surface) must be the foundation, it is only necessary in order to accomplish this object to treat of the experience-coefficient c of the formula $v = c\sqrt{RJ}$. This coefficient c (according to Eytelwein equal 50.9 for the metre measure) receives according to the new formula the following different expressions:

1. According to Humphreys & Abbot

$$c = \frac{5.86\beta}{\sqrt[4]{J}};$$

β varying between 0.85 and 0.97.

2. According to Bazin:

$$c = \sqrt{\frac{1}{\alpha + \frac{\beta}{R}}};$$

α and β varying according to the degree of roughness of the the wetted perimeter.

3. According to Gauckler:

With a fall of over 0.0007

$$c = \alpha\sqrt[6]{R}$$

With a fall of below 0.0007.

$$c = \beta\sqrt[6]{R^5}\sqrt{J}$$

α and β varying with the degree of roughness of the wetted perimeter.

Although these expressions for c are very different, and although those of Humphreys and Abbot vary only with the fall, and almost not at all with the value R, those of Bazin only with the value R, and with the degree of roughness of the wetted perimeter, and lastly, those of Gauckler on one side like those of Bazin, and on the other with a fall below 0.0007, with the values of R and J, and the degree of roughness of the wetted perimeter; still all the formulæ give good results within certain limits. The American formula gives good results with waters having a small fall, whereas they are useless with a large one. The formulæ of Gauckler and Bazin are good in all cases, excepting that of large rivers with small fall, as, for example, in case of the Mississippi, where the fall is very small. In that case the second formula of Gauckler gives the variation of the values of c exactly opposite to the results obtained by measurement, namely, that c increases with J, whereas the opposite takes place at the Mississippi. If the different values of c of the common formula $c\sqrt{RJ}$ are computed by each of the above formulæ, for a current table of the values of R, and then drawn on a scale as ordinates whose abscissas are represented by the values of R, very different curves are produced by the formulæ of Humphreys and Abbot and those of Bazin and Gauckler, namely:

1. If the same fall is retained in the formulæ of Humphreys and Abbot a curve

*Translated from the German of Ganguillett and Kutter.

slightly increasing with the value of R is produced, which approaches to the right line in the same proportion as the assumed fall is increased. As the coefficients c vary with the fall there must be a different curve for each separate one. If the fall (J), however, is assumed to be the abscissa with a constant value of R, an upward tending hyperbolic curve is produced, according to which c becomes largest with the smallest fall, and smallest with the largest fall, as was very plainly seen by the results of measurement of the Mississippi and other large streams.

2. According to the formula of Bazin the curve produced by the values of c increases at first very rapidly, with the increase of the value of R afterwards, however, (for example, from R = 0.3 up) less and less, until at last with large values of R (for example R = 5) it becomes nearly a right line. Assuming $R = \infty$ in the formula,

$$c = \sqrt{\frac{1}{\alpha + \frac{\beta}{R}}}$$

then $\beta = 0$, and c has for the four categories the following constant rules:

Category I.	$c = 81.65$	Diff. 9.10.
II.	$c = 72\ 55$	
III.	$c = 64.55$	" 8 00.
IV.	$c = 59.76$	" 4.79.

It is therefore assumed in the four formulæ of Bazin, that the degree of roughness of the wetted perimeter influences the motion of the water to infinity, and that the differences which these degrees have in regard to the values of c, and consequently also produce the medium velocities, are constant quantities in infinity.

In the maximum case $c = 81.65$ according to Bazin. But at the Mississippi there are four coefficients deduced from the general expression $v = c\sqrt{RJ}$, by the results of ten measurements, and all of these range above 81.65, the maximum being as high as 140.

3. The series of the values of c which are computed by the formula of Gauckler

$$\sqrt{v} = \alpha \sqrt[3]{R^4}\sqrt{J}$$

and which contain maxima and minima values for six categories, increase at the beginning very quickly, with the value of R; after that, however, less and less, but still increasing, and become in case of the maximum and minimum value R = 100, in

Category I.	215.4 to 155 6
II.	155.6 " 124.4
III.	124.4 " 99.6
IV.	99.6 " 70 0
V.	70.0 " 53.9

and when $R = \infty$, all $= \infty$.

In the second formula, which is applicable in cases where the fall is less than 0.0007, the values of c are dependent on R and J.

In the following table, we give the computed maxima and minima results for a few falls below 0.0007, in order to illustrate the increase of the values of c with that of the value of R, and the decrease of the former with the decrease of the value J.

R.	J = 0 00069	J = 0.0003	J = 0.0001	J = 0.00001	J=0.000001
0.1	25.4 to 6.5	16.7 to 4.3	9.6 to 2 6	3 0 to 0 8	1.0 to 0 3
0.5	96 8 " 21.8	63. " 16.3	36.8 " 9 4	11.6 " 2.9	3.7 " 0 9
1.0	172.5 " 44 2	113 5 " 29 1	65.6 " 16.8	20.7 " 5 3	6 6 " 1.7
5.0	659.8 " 169 0	433.9 " 111.1	250 8 " 64 2	79 2 " 20 3	25.1 " 6.4
10	1175.5 " 300 7	773.4 " 199 0	446 9 " 114.5	141.2 " 36 2	44 7 " 11.4
100	8008.0 " 2049.7	5267.7 " 1349.0	3044.9 " 779.5	962.1 " 246.4	304.5 " 77 9
∞	∞ ∞	∞ ∞	∞ ∞	∞ ∞	∞ ∞

From, this it will be seen at once that with an equal value for R but unequal one of J, the values of c decrease with the decrease of the fall, whereas at the Mississippi and other water-ways the contrary takes place. It will be further noticed that, for example, with a fall of 0.00069, which takes place at least in Switzerland and also in larger rivers, for the value of R = 3 the minimum value of c rises already to 110; again, when R = 4, c = 140, R = 5, c = 169, whereas in reality it ought not to amount to more than barely 60.

In these minima cases $\beta = 6.4$ assuming $\beta = 7.0$, in which one would be justified, according to Gauckler, in rivers without water plants; then, when

R = 3, c = 158
R = 4, c = 200
R = 5, c = 241

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From the following table it will be seen that when in large rivers comparative large fall exists, the coefficient β should be considerably below 6.4.

Canals and Rivers.	R	J	Measurement V	Instead of $7\beta =$
Linth canal	2.704	0.0003600	1.644	5.9
Weser, near Vlotow	4.069	0.0005500	2.409	5.1
Elbe near Magdeburg	4.025	0 0003630	1.630	5.1
Chesapeake canal	1 116	0 0006985	0.830	5 7
Bajou La Fourche	5.593	0.0002064	1 584	5.3
Mississippi	20.081	0.0000680	2.121	4.9

Finally it will be seen that according to the second formula $\sqrt[4]{v} = \beta \sqrt[3]{R} \sqrt[4]{\beta}$ the value of the coefficient c of the expression $v = c\sqrt{RJ}$ increases still more than in the first formula $\sqrt{v} = \alpha \sqrt[3]{R} \sqrt{J}$, also that in infinity they also become infinite, and with them the differences which are accounted for by the different degrees of roughness of the wetted perimeter.

As the coefficient β, in reference to the average rapidity, has to be raised to the fourth power, it is of great importance in the projection of canals, that it should be determined beforehand with the greatest accuracy, for which reason we think that in this case the limits should be established as 7.7 and 5.0 instead of 7.7 and 6.4.

Starting from the supposition that the degree of roughness of the wetted perimeter has great influence on the flow of the waters, we had already at an earlier period tried to introduce the value p (wetted perimeter) in the formula, with that length which would be obtained when, for example, in existing inclined strata (of rock), all semi-circumferences of the stones, the roughness of the bank protections, etc., could be followed and the length thereof accurately measured. We thought that $1.8\,p$ could be assumed as extreme limit, and only then as unchangeable, when entirely smooth walls, such as boards, were under consideration. In spite of all trouble, however, we could not succeed in establishing the value of the factor with which p had to be multiplied in the different cases, and which indeed can only be obtained by accurate measurement and observations of the rapidity of canals whose wetted perimeters exhibit different degrees of roughness. This problem has, however, been solved in a complete and splendid manner by Darcy & Bazin.

As we have seen, the formulas of Bazin contain the supposition that when $R = 0$ the coefficient c must also be zero, and when $R = \infty$, it must remain a constant quantity. As in this case each category retains its constant coefficient c, this formula expresses, that the differences of the influences of the different degrees of roughness of the wetted perimeters take place with waters of infinite dimensions in the same measure as with the larger streams. In that case the formulæ give for the following values of c when $R = 25$ (Mississippi), and $R = \infty$

	$R = 25.$	$R = \infty$
Category I.	$c = 81\ 60$	.... 81.65
II.	$c = 72.50$	.... 72.55
III.	$c = 64\ 30$	.... 64.55
IV.	$c = 58.32$	.... 59.76

In reference to the first supposition, that that when $R = 0$, the value c would also equal zero, it is to be remarked that the graphically represented values of c, of all the results of measurement of Bazin, which he took at the experimental canal, would lead to the supposition that the values of c would not equal 0, even if $R = 0$, but that the curves of these series cut the axis of ordinates in certain points, which possibly could take place without disadvantage. But the results obtained from the small wooden flume of a breadth of only 0.1 metre, show in a graphic representation such a decided tendency towards the zero point that one will be obliged to let the curve pass from the zero point through these series.

The other supposition, that the differences of the degrees of roughness of the wetted perimeter exert an equal influence on a stream of infinite depth and breadth as on one of given dimensions, seems to be inadmissible. It is of course impossible to give proof either for or against this supposition, as no experiments could be made; supposing, however, that different reaches of the Mississippi (40 metres deep, and from 1,000—

1,500 broad) could be lined with smoothed cement, with cut sandstone or bricks, with boards or masonry of small pieces of stone, or that it was covered by inclined strata of stone running almost in the same direction as the water, it will without doubt be admitted, that if these different degrees of roughness will still be felt at the side and bottom, and will exert an influence on the movement of the water in the vicinity of the wetted perimeter, it cannot influence this enormous mass of water as it would in case of small canals or waters. As the irregularities of the surface against which the water strikes, are very small in proportion to the whole surfaces of the cross profile, of course the influence exerted by these thrusts is less on the whole body of water in a large mass than in a small one. If the whole surface of such impediments, for example, in a water cross profile of 10 cubic metres would amount to 0.001 cubic metre, then it would only be 0.0001 part of the entire cross profile. With such a profile of 20,000 cubic metres (Mississippi), these surfaces are only equal to it two millionth part. At a stream of infinite dimensions, the proportion of the surfaces of impact to the cross profile becomes infinitely small or zero.

We assume, then, that the difference of the influences of the roughness of the wetted perimeters, as shown by the experiments of Bazin, was in infinity not a constant, and much less, as per formula of Gauckler, an infinite quantity, but equal to zero. According to this fundamental proposition, this difference decreases with the increase of the value R, but only equals zero when the latter equals infinity. For the present we will remark that with our formulas when $R = \infty$, $c = 100$ in all categories, then

Category I.	$c = 99\ 8$
II.	$c = 98.5$
III.	$c = 98.0$
IV.	$c = 97\ 4$
V.	$c = 96.9$

In order to translate this proposition into a formula, which, like that of Bazin, has for each category a corresponding coefficient, and besides a constant coefficient, representing the value c in infinity or the maximum case, Chief Engineer Gauguillet chose the expression

$$c = \sqrt{\frac{1}{\alpha + \frac{\beta}{R}}}$$

from the more convenient new formula of Bazin & Darcy. As the value of α and β are small, decimal fractions, inconvenient for computation, the four formulæ of Bazin were changed into such as contain coefficients of whole numbers, in the following manner:

Executing the division in the expression

$$\frac{1}{\alpha + \frac{\beta}{R}}$$

we have then

$$\frac{1}{\alpha} - \frac{\frac{1}{\alpha} \times \frac{\beta}{R}}{\alpha + \frac{\beta}{R}}$$

$$\frac{1}{\alpha} - \frac{\frac{\beta}{\alpha R}}{\frac{\alpha R + \beta}{R}}$$

or

$$\frac{1}{\alpha} - \frac{\frac{\beta}{\alpha}}{\alpha R + \beta}$$

and finally

$$\frac{1}{\alpha} - \frac{\frac{\beta}{\alpha^2}}{R + \frac{\beta}{\alpha}}$$

Letting

$$\frac{1}{\alpha} = a, \frac{\beta}{\alpha} = b, \text{ and } \frac{\beta}{\alpha^2} = a\,b,$$

then

$$\frac{1}{\alpha} - \frac{\frac{\beta}{\alpha^2}}{R + \frac{\beta}{\alpha}} = a - \frac{a\,b}{R + b}$$

and hence

$$c = \sqrt{a - \frac{a\,b}{R + b}}$$

The principal formula of Bazin becomes instead of

$$v = \sqrt{\frac{r\,s}{\alpha + \frac{\beta}{R}}}$$

equal to

$$v = \sqrt{\left(a - \frac{a\,b}{R + b}\right)} R\,J.$$

In this new formula a is the constant coefficient which represents the maximum case, and the coefficient $\frac{a\,l}{R + b}$ is the one which is to be determined for each category and which varies with the value of R. In reference to this coefficient and in order to make the figures smaller for the value of a

and b, and specially to have the coefficient $a - \frac{a\,b}{\sqrt{R}+b}$ outside of the root sign, we omit this sign in the expression

$$\sqrt{a - \frac{a\,b}{R+b}}$$

and replace R by $\sqrt{R}$, which gives the formula the following shape

$$v = \left(a - \frac{a\,b}{\sqrt{R}+b}\right)\sqrt{R\,J}$$

by which the values for a and b are correspondingly changed.

This is our new formula, in which a contains the value c of the common expression $v = \sqrt{R\,J}$ in the maximum case, and the results obtained by it are as correct as those of Bazin and Gauckler.

It is evident that when in this formula $R = 0$, $a = 0$, and when $R = \infty$,

$$\frac{a\,b}{\sqrt{r}+b} = 0.$$

The determination of the coefficients a and b conformed to category No. 1 in which the smoothest wetted perimeter is assumed, which is, according to the results of Bazin, the case in a canal of semicircular form, built of cleaned and smoothed cement (Series No. 24), and a small canal constructed of carefully planed boards (Series 28, 29). In Series No. 24 with an assumed value of $R = 0.25$, those ordinates were found, through whose origin that curve passes, which was found by our formula commencing at the zero point and ending at the maximum value a, and which, passing through all the ordinates of the observation series, must keep the middle. These ordinates are the values of c computed from the results of measurement. The middle ordinate with $R = 0.25$ for category I. was found to be 81. About the constant coefficient a, which represents the maximum case, it is necessary to remark that in our formula the influence of the variation of the fall, with equal values of R, as in the formula of Bazin, is for the same reason not taken into consideration, as we assume that this influence at smaller waters than the Mississippi, specially however at artificial canals with strong fall, which are represented in most of the categories, can be left out of the question. Should it be deemed necessary to take it into the computation, the observations already made and those made made further on, in the description of the categories, will be of use, and lead to show the proportion in which the coefficient contained in the formula, relative to this influence of the variation of the fall, must be increased or decreased.

At the Mississippi this influence is very evident, and as the new formulæ of Humphreys and Abbot are perfectly adapted to the case, as none of the others are, they always ought to be used at such a stream.

In order to determine the constant value a, we had to assume that this value should denote the limits of possibility, when the influence of the variation of the fall is not taken into consideration, and we took for this purpose the results furnished by the Mississippi, in which case we could not expect larger errors in our proportions, which are very different from those of that mighty stream. When we assumed a too large, our curves became too high, and lost the direction which the results of measurement seemed to indicate; when we took it too small, however, the curves were below these results. We therefore concluded to take the arithmetical mean of the maximum and minimum values of c at the Mississippi $= 100\left(\text{from}\frac{60+140}{2}\right)$ which direction also seemed to be the one indicated by the results of measurement.

If, in Series No. 24, the values of c rise from 73 to 87 with the values of R varying from 0.1 to 0.3, one would be tempted to think that the maximum must rise above 100; but the average curve of all 12 values of c points also nearly to 100.

It is self-evident that if our curves starting from the zero point, all pass through a given point in an observation line, this would also have been the case had we assumed a, a little larger or smaller.

In relation to the determination of the coefficient b, it can be said

$$b = \frac{100 - c}{c}\sqrt{R}$$

As in our case $c = 81$, and $\sqrt{R} = 0.5$, then $b\ \frac{100-81}{81}\ 0.5 = 0.117$.

We have found that when only four categories were assumed there were large intervals between every two of them, and as there is no impediment to establishing as many series of coefficients as necessary, we established the number at 12, and took care in determining the coefficieut b that the curve produced by the 12th series under

the results of measurement for waters running over rough inclined strata, should keep as near the middle as possible. The other 10 series were taken at equal intervals between the 1st and the 12th, without using a result of measurement. As neither the formula of Gauckler, Bezin, or ours are sufficient in all cases, but can only be considered as safe halting places in the wide range of coefficients; we have found it better instead of forcing a number of different results under the different formulæ, only to give a sufficient number of reliable measurements and to show how much they differ from the nearest series of coefficients, and what modification they need in order to adapt them to these results of measurement.

We have then 12 formulæ, each one of which gives a value for the coefficient c of the formula $v=c\sqrt{\mathrm{R}\,\mathrm{J}}$ for each given value of R, and when R=o, c=o, and when R=∞, c=∞. We only mention in addition, that with Series No. 1, for R=0.25, and c=81, we have found b=0.117. In order to facilitate computation, this was reduced to 0.12, which, without disadvantage, gives c=83.3 instead of c=81, in which case, however, it must not be forgotten that for Coefficient Series No. 1, we only found one set of results, and that with little change of that curve the results of the Series Nos. 28 and 29, which are placed nearer the zero point, no appreciable modification of the curve can take place.

Our twelve formulæ are:
Fundamental formula

$$v=\left(a=\frac{a\,b}{\sqrt{\mathrm{R}}+b}\sqrt{\mathrm{R}\,\mathrm{J}}\right.$$

$$c=a-\frac{a\,b}{\sqrt{\mathrm{R}}+b}$$

Series of coefficients:

I. $c=100-\dfrac{12}{\sqrt{\mathrm{R}}+0.12}$

II. $c=100-\dfrac{15}{\sqrt{\mathrm{R}}+0.15}$

III. $c=100-\dfrac{20}{\sqrt{\mathrm{R}}+0.20}$

IV. $c=100-\dfrac{27}{\sqrt{\mathrm{R}}+0.27}$

V. $c=100-\dfrac{35}{\sqrt{\mathrm{R}}+0.35}$

VI. $c=100-\dfrac{45}{\sqrt{\mathrm{R}}+0.45}$

VII. $c=100-\dfrac{56}{\sqrt{\mathrm{R}}+0.56}$

VIII. $c=100-\dfrac{72}{\sqrt{\mathrm{R}}+0.72}$

IX. $c=100-\dfrac{93}{\sqrt{\mathrm{R}}+0.93}$

X. $c=100-\dfrac{122}{\sqrt{\mathrm{R}}+1.22}$

XI. $c=100-\dfrac{167}{\sqrt{\mathrm{R}}+1.67}$

XII. $c=100-\dfrac{244}{\sqrt{\mathrm{R}}+2.44}$

SEWER GAS—A SYSTEM OF HOUSE DRAINAGE.*

By OSBORNE REYNOLDS, M. A.

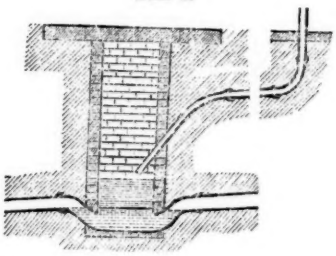
The art of properly draining buildings is distinct from that of sewering of towns or districts. This is fortunate, for be the sewer or cesspool into which a house drains never so foul, it may be beyond the power of the unfortunate inhabitant to get it set right. He must rely on the subsoil on which his house stands, and on the floor and walls of his house to separate him from the contents of the sewer. He must rely on these and on an artful connection of the drains within his house with the poison generator without, so that they may serve to carry off the refuse without affording a passage back for the poisonous gas. In order to do this effectually it is necessary that all the drains in the house should flow into one pipe so that there may be only one connection between the house and the sewer, and in this pipe there must be a trap of somewhat peculiar construction. This trap is shown in Fig 1.

A man-hole or shaft is sunk from the surface to the pipe, the floor of the man-hole being about 2 ft. above the bottom of the drain. Across this floor there is an open trough which takes the place of the pipe; this is about 2 ft. deep, and of the same width as the pipe. The ends of the pipe which are connected with the trough are

* Sewer Gas and how to keep it out of houses. A handbook on house-drainage, by Osborne Reynolds, M. A. London: Mc Millan & Co.

(as shown in the diagram) so depressed that the water stands in the trough about half an inch above the orifice on the sewer side, and an inch above the mouth on the house side. In this way a trap is formed which effectually closes both the house and the sewer from the man-hole and doubly closes the house from the sewer. And if care is taken to arrange the orifices of the pipes in the man-hole as recommended, it will not be possible for the water to be

FIG. 1.



sucked out of the trap, should the pipe run full. The man-hole affords a ready means of examining or cleansing out the trap, but in order to prevent a scum forming on the surface of the water in the trough, the pipe from a roof spout may be arranged so as to discharge itself on to the top of the trough, as shown in the diagram.

The drain from the author's house is deep, and the shaft is 2 ft. square, built of 4½ in. brick work, the bottom formed of bricks and cement; the trough is cemented. The pipe is 5 in. inside. The charge for constructing the whole was less than £3.

In most cases a simpler plan will be found to answer quite as well; instead of having a man-hole and trough, a special earthenware trap is used, such as is shown in Fig. 2.

FIG. 2.

The length of the upright branch should be increased with straight pipes until it comes to the surface, where its mouth may be protected but not closed. In one of these pipes there should be a side junction for connection with the down spout, as shown in Fig. 8.

Such a trap may be put in any position, and need not cost £1. They are, or should be, kept by all vendors of sanitary pipes.

The best position for such a trap as this will be determined by circumstances, but it must be somewhere between the house and the sewer, branch sewer, or cesspool into which the house drains. As a general rule the nearer the house the better.

It is, however, to be insisted on that all the drains in the house shall flow into this trap,—that there shall be only one connection between the house and the sewer, or at least if there be more they shall each have a trap, and be certain of a constant supply of water sufficient to maintain the necessary level in it; for it is to be specially noticed that the essence of this improvement is to insure the action of an efficient trap, which can only be the case when the water supply is unfailing.

The reader will be better able to appreciate the reasons why this particular form of trap and the position assigned to it are specially recommended, when he has read the discussion in the following sections on the general arrangement of house drains and traps. The further consideration of these questions has therefore been deferred to the Fourth Section.

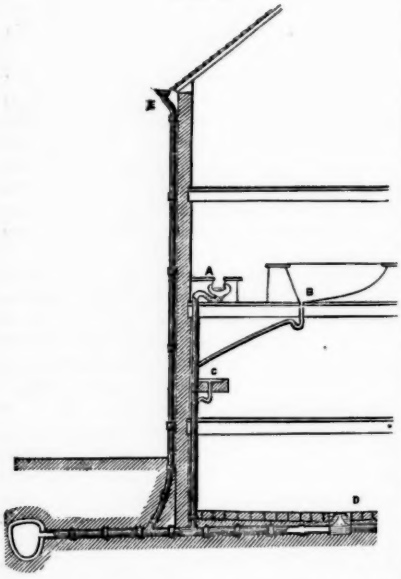
It is not necessary to have these traps for cottages and houses without cellars or water-closets, but it is equally important that in such there should be no direct connection between the drains from within and the sewer. The only essential drain from the inside of such houses is the pipe from the sink. For reasons which will be explained hereafter, it is not safe to depend on a trap in this pipe. Perfect discontinuity should be insured by bringing the pipe through the wall of the house, above ground, so that it may discharge into an open trough or gutter leading to a yard or street gully. The mouth of the pipe should not be directly over the gully, otherwise the light gas from the gully may rise up it, and thus find a way into the house.

II.—ON THE PURPOSE AND GENERAL ARRANGEMENT OF HOUSE DRAINS.

The first thing for the anxious householder to do is to get a clear conception of what the drains in his house are for, and whereabouts he may expect to find them. The accompanying diagram will very much assist him in this. He will at once see that the necessity of the house drains arises from

the use of water-closets, baths, sinks, and underground cellars, and that whatever may be their subsequent directions, they start from one or other of these sources. Fig. 3 represents a section of an ordinary town-house, taken so as to show all the usual inlets into the drains; A, the closet; B, the bath, C, the sink; and D, the cellar drains. It also shows the sections of the pipes from these sources, and the manner in which they are usually connected with each other and the outside drain. In this example the house drains are shown connected with a branch sewer which runs at the back of the house (a very common arrangement in towns); but it is not intended to

FIG. 3.



confine these remarks to houses which drain in this way, for they apply equally to houses which drain directly into a street sewer, or into a cesspool.

The most important drain in a house is the soil-pipe from the closet (A). It is, generally speaking, metal between the closet and the ground. Sometimes this part is entirely of lead, but more commonly of lead and iron; the straight part being of iron, for cheapness, and the rest of lead, for convenience of manufacture. This pipe should be, and generally is, about five inches across inside. There is usually a bend in it immediately below the pan of the closet; a depression which, standing full of water, prevents the smell from coming up the pipe into the closet. In most houses the water-closet is above the ground floor, and the pipe has to descend for some distance before it reaches the ground, and it seems to have been an open question whether it is more objectionable to have the pipe with its smells, for these pipes are never smell-tight, inside the walls of the house, and protected from the frost, or to carry it at once through the walls and bring it down outside in the open air.

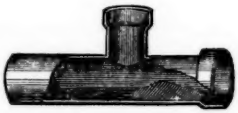
If the smells are kept out of this pipe, as will be the case when the house is disconnected with the sewer, in the manner described in Section I., the pipe may be safely kept inside the walls without any fear of its giving out bad smells or sewer poison.

The minor waste pipes, those from the sinks and bath, often join the down pipe from the closet. They are themselves generally leaden pipes about one inch in diameter, and they are connected with the cast-iron pipe by means of putty joints, and it is at these joints for the most part that the pipe leaks or the smells escape. There are usually depressions in these lead pipes which are supposed to keep full of water and prevent smells coming up the pipe, but these often fail from a fault in construction.

The closet-pipe brings the refuse from all its tributaries down to the ground, and sometimes as low as the cellar-drain. The metal pipe is then connected with an earthenware pipe of the same size, or larger, which is laid with sufficient fall in the direction of the sewer or outlet. The junction between the vertical iron pipe and the glazed earthenware is of some importance. It is often made with a square elbow or branch. This is particularly the case where the iron pipe descends inside the house, and the earthenware pipe is the continuation of the drain from the cellar, as shown in Fig. 3. This square connection is bad wherever it exists. In the first place, the water falling straight down on to the bottom of the horizontal pipe makes a splash and loses all the impetus it had acquired in falling, which if properly directed would have been of great use in carrying it past or removing any obstructions there might be to its subsequent course in the flat pipe; and in the second place, where the closet pipe simply branches from the cellar or

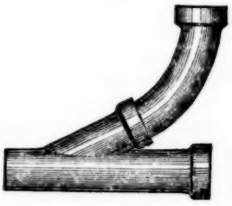
some other drain, the splash at the bottom is apt to leave a deposit, as shown in Fig. 4, on the upper side of the connection, which can only be removed by a flush down the drain from some other source. When practicable, all junctions should be effected with curved bends such as those shown in Fig. 5, so that when the pipes come together their contents may be flowing as nearly as possible in the same directions.

FIG. 4.



Perhaps of all the drains in the house that from the cellar is the most liable to be the source of mischief. It is the lowest, and consequently has the worst fall; and if its lawful contents are not of an offensive kind, yet, owing to its position, it often receives the contents of its more ill-favored neighbors. Besides this, it is out of the way, it gets less attention than the others, and in many cases it is not directly used, and so has not the advantage of an occasional flushing. In many old houses in the country it is constructed of brick or of unglazed pipes. In modern houses it is of glazed earthenware pipes about 5 or 6 in. across, and sometimes as much as 9. These are all larger than is necessary, a 3 or 4-in. pipe with a fall of $\frac{3}{4}$ in. to the yard is amply sufficient.

FIG. 5.



In many houses, such as those in the neighborhood of Manchester, there are cellars (not kitchens) under the whole house, and each cellar has its gully and drain. Now, it may be convenient to have sinks all over the house; but when we come to think how seldom these cellars are washed, or indeed have any water in them, it seems almost unnecessary to have drains all over them just to save the servants the trouble of occasionally washing a yard or two of floor. Of course if the drains were harmless, that would be all very well; but when we consider that there is difficulty and danger about every drain, and especially the cellar drains, and that every extra foot or yard is just increasing the danger by so much, we must submit that to have a ramification of drains under the whole house is likely to cost us dear for the convenience it brings. There must be one drain from the lowest part of the cellar, but this need only just come through the wall.

Besides these drains from the inside of the house, those from the spouts (E), Fig. 3, which carry off the roof water, often form part of the same system. They are sometimes kept distinct, and communicate with the sewer by separate pipes, but more commonly they are connected either with the drain from the cellar or the soil pipe. Some people have recently made a point of doing this with a view to ventilate the drains and form a way of escape for gas that would otherwise force its way into the house. This, however, is a mistaken idea. The plan need not be mischievous, it is often the reverse, but it is done under a similar misapprehension to that which leads people to have openings in their ceilings to take out the hot air from rooms, the fact being that, when there is a fire in the room, the draught up the chimney is so great that it draws air into the room at every crevice, and consequently the opening in the ceiling which was intended to take air out lets air in, and thus acts in a manner the reverse of what was intended. So it is with the drains. The suction of the house, especially when fires are lighted and windows closed, draws so much air out of the sewers that they have to get it where they can, and all the openings into them from the outside, the down spouts among the rest, are actually letting air into the sewers instead of out of them.

Such, then, is the most common arrangement of drains in a house, and there are obviously two ways in which these drains may be the means of poisoning the inhabitants; they may introduce the much-dreaded sewer gases, or they may themselves become filthy and give off effluvia. The following parts of this pamphlet are devoted to the consideration of these evils in detail, both in respect to their cause and cure.

III.—HOW GASES ARISE FROM THE DRAINS, AND THE PREVENTION THEREOF.

If drains are made of a porous material such as brick, or unglazed pipes, they will necessarily be offensive; this will also be the case if they are badly laid, so that they have hollows in which water stagnates. It must always be remembered that sewage when fresh is almost innocuous compared with the same when decomposing, and that the rate of decomposition is immensely increased by the presence of some already decomposing sewage, which acts in the same way as yeast; thus sewage stagnating in, or flowing through, dirty drains, will become offensive much more rapidly than if the drains are clean.

Those drains which are underground are particularly liable to these evils, and in addition are sometimes leaky, in which case they saturate the ground around them with stinking liquid.

It is of the first importance that these underground drains, especially if under the house, should be well laid and composed of the right material. Fortunately there is no difference of opinion as to their proper construction, and in most modern houses they are well done. They should be composed of earthenware pipes (not cast-iron), socketed, and jointed with cement. There is an objection to making the joints with cement, which often prevents its being done. It makes the pipes very rigid, and as the ground under new houses is liable to settle, there is fear lest the pipe should be broken. This, however, will not happen if care is taken to lay the pipes on a natural or well-rammed, or, in bad places, a concrete bed.

The ordinary plan of jointing the pipes with clay-puddle, though probably the best for sewers, is not so good under a house where it will get dry, and where economy in such matters sinks into insignificance compared with efficiency and safety.

The drains above ground are generally of metal, and it is only in the depressions which are intended to form traps that stagnation can take place. This stagnation is the cause of an evil often complained of, viz., that when fresh water is let into a trap a smell comes up; as, for instance, when the pan of the closet is lifted and its charge sent down into the trap, there is often a bad smell, although apparently none at other times. The fact is, that the trap beneath the pan stands full of filthy water, and the pipe between the pan and the trap is full of the effluvia which the contents of the trap give off. So that when the pan is raised the condition of things below is disturbed and the effluvia rises. The obvious remedy for this is to allow sufficient water to go down each time to change the contents of the trap and leave it full of pure water. More will be said on this subject further on in the book.

The size of the pipes is of some importance. It is a common mistake to make some drains too large. It must be remembered that the smaller a pipe is, the better it is flushed, and the less liable it is to get blocked so long as the inlet is properly protected by a grate. From the nature of its work the closet-pipe should not be less than 5 in.; but such a pipe is large enough to form a branch sewer to take the sewage from half a dozen small houses; for the cellar-drains, a pipe of 3 or 4 in. is quite large enough.

With regard to the fall in the underground pipes, it is of more importance that this should be regular than that it should be great. A common rule is to allow $\frac{3}{4}$ in. fall in the yard. This is quite sufficient, and where necessary a smaller fall may be used, provided the pipes are laid with great regularity.

In modern houses the drains are generally well laid, and consequently do not commonly generate gas within themselves. Hence, in such houses precautions should be first taken to prevent the gas from the sewers getting into the drains; after which, if there is any further smell, the drains themselves must be looked to.

IV.—HOW THE SEWER GAS ENTERS HOUSES—THE CURE OF THE EVIL.

The entrance of sewer gas by the house-drains has been the subject of as much discussion within the last few months as if it was a new discovery; but this is not the case, for, if it had been unknown before, why have we traps, and not only traps, but laws to cause the use of traps, on the mouths of all drains? It is not the tendency of this gas to get in that has been recently discovered, but the inadequacy of the measures hitherto taken to keep it out.

But although the fact that smells and bad air do force themselves from the sewers is well known, it is not so clear why they do so. Judging from the newspapers, this is generally attributed either to an excess of

pressure in the sewer arising from the fermentation of its contents, the backing up of water in the outlets of the sewers, or the pressure of wind on these outlets; or else to the lightness of sewer gas, which causes it to ascend by levitation wherever ascent is possible.

The first of these causes is much overrated, in fact it only exists at all under exceptional circumstances, as, for instance, near the outlet of a large sewer on which the wind is blowing. Whenever experiments have been made to ascertain the excess of pressure in the sewers of a town, contrary to expectation the pressure within the sewer has been found less than that without. Nor, as we shall see, is it at all difficult to find a reason for this. Sewers must not be looked upon as so air-tight that a small quantity of gas has a difficulty in escaping from them; there is generally what may be called free communication between the sewer and the outer air, so that it is impossible there should be an appreciable difference of pressure within and without.

The second cause no doubt exists; the drains are all laid with a falling gradient from the house to the sewer, and consequently they rise from the sewer to the house; and the light gas will ascend in the opposite direction to that in which the water falls.

Now, possibly some of the evil is due to this cause, but far more to the following, viz. the suction of a house produced by the chimneys, or even the warmth of the house itself.

This suction of the house, although a very small quantity in actual pressure, being always less than one-eighth of an inch of water, *i.e.* not sufficient to suck water up a tube one-eighth of an inch, and consequently never sufficient to suck the air past a good trap, is sufficient to cause a great deal of air to enter by a very small opening. This will be at once perceived by holding the hand over the crevice of a window in a room with a fire. Hence, be there cranny or crevice into a drain, the house will suck gas, whatever be its source. This is the reason why there is a minus pressure in the sewers; the houses which drain into them are making larger demands for gas than can be supplied by the fermentation of their contents, or wind that may enter at their distant outlets.

We see, then, that there are two inducements for the gas to enter the house. Now the distinction between them has not received due attention; they have been confused together, and as the same preventives which are efficient for the one are no use for the other, the attempts to prevent the gas entering have been failures. If the effort of the gas to escape from the sewer were the only reason why it enters the house, this would be satisfied by providing it with a more ready means of exit from the sewer, such as street gullies, shafts, or down spouts. But as the suffocated houses suck away at the drains, air will be drawn out, however many other openings there may be into the sewer, which only serve to let fresh air in. Hence no amount of ventilating shafts can be efficient to cure the evil. Nor is it practicable, as has been proposed, to produce effective exhaustion in the sewers by furnaces, for the simple reason that the sewers are not sufficiently air-tight.

It is not, then, enough simply to prevent the sewer forcing or breathing gas into the houses, we must prevent the house sucking the gas out of the sewer. This is what drains on the usual system fail to do; the reason why they so fail will appear when we consider the principle on which they are supposed to act. The drains themselves have free communication with the sewer, and are therefore always filled with sewer gas, and if the house is not to suck this gas from the drains, it is necessary in the first place that the inlets or mouths of the drains should be efficiently trapped; and in the second place, that the drains themselves should be air-tight as well as water-tight.

Now, to consider the latter of these conditions first, viz., the making the drains within a house perfectly air-tight. It may be possible to make them so for a short time; but in practice it is found impossible to keep them so. As we have seen, these drains are of different sizes and composed of different materials; this makes it very difficult to joint them tightly. The metal pipes alter in length with the temperature, and the expansion breaks the putty or cement joints. If, as in the case with gas or water-pipes, leaks manifested themselves with certainty, we might depend on occasional repair to keep these drains tight; but such is not the case. There is positively no means of ascertaining whether the pipes are sound or not. A smell often shows that they are not tight, but its absence does not prove them to be so.

It is found practically impossible to make

the joints tight (especially those between the lead and iron pipes), and in the face of this fact and that just mentioned, that we have no means of ascertaining when they want repair, it is unscientific to trust to this way of keeping the gas out of houses.

Again, to go back to the traps, is it possible to close the mouth of the pipes against gases and leave them open to the refuse liquid? This can only be done under certain circumstances; then it is done by a water-valve, commonly called a stench-trap. These, though of great variety, are all on the same principle. This principle is very

FIG. 6.

simple, as may be seen from the commonest and simplest form of trap—a depression in the pipe, which stands full of water, and therefore closed against the gas, after the rest of the pipe is clear.

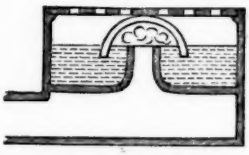
Many so-called traps are defective in construction. Sometimes the depression is too shallow, so that when this is full the passage is not completely blocked; but sometimes, where the depression is deep enough, the trap fails from the fact that of the water which runs through, none, or only a little, remains in it. This is the case with a pipe so small in proportion to its work that it runs full; for if there is sufficient fall in the pipe below the trap, the water in this portion of it will, by its siphon action, empty the depression. This is a very common fault with the traps in small lead pipes; most plumbers are alive to it and make traps in such pipes of a larger size than the pipe itself.

But it is not only faulty traps that fail; the best trap will not act unless it has water in it; and, since water evaporates, there must be a constant, at least a frequent, supply of water through the trap to render it effective. Now, many of the drains commonly put into a house have no water through them by the month together, and where this is the case, even if the water does not leak out of the trap, it will dry up and the trap be left open. This is particularly the case with the cellar traps, which are often out of the way and unnoticed.

Again, if dirty water stand in a trap for a few hours, it becomes putrid, especially if there be any putrid water in the trap to begin with. Hence, any trap which is likely to be left full of dirty water is liable to cause nuisance in a house. There is a great liability of this happening with the trap under the pan of a water-closet. This is often so large that there is not enough water in each discharge to make a sufficient change in the contents of the trap; and where with such a construction the closet is only used once or twice a day, the trap is sure to get very dirty. This liability is cured if the trap is left full of clean water, or if there is a frequent flow through it, clean or dirty.

There is, however, another difficulty with traps: being, as we have said, essentially depressions in pipes, they are apt to arrest

FIG. 7.



sediment, and become choked up with it. This is very liable to happen in the cellar drains, where the dirt from the floor is washed into the gullies. From this reason alone the bell-trap is generally used in cellars, because it can be cleaned out with facility; but it is objectionable from its peculiar liability to dry up.

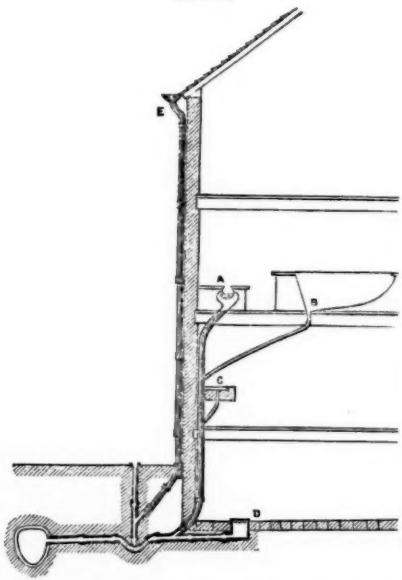
To prevent traps from becoming blocked in this way, it is necessary that water should run through them with sufficient velocity to flush them, *i. e.*, carry the sediment out along with it. Where the ordinary flow is not sufficient for this, it must be done occasionally by a special effort.

Thus we see what the conditions are under which a trap will act with certainty, viz.: when the pipe is sufficiently large not to run full, and when there is a frequent flow of water through it. Now, no traps inside a house exist under such conditions, unless it be that in the closet-pipe, and that not always; hence it will be an advantage to get rid of these inlet traps altogether, and supply their place by another trap placed under more favorable circumstances.

The sewer gases will be as effectually kept out of the house if they are kept from entering the drains, as if they were prevented from leaving them. In fact, these drains are passages; and, if we can stop the

passages at either end, it will answer our purpose equally well. And, for reasons which are very simple, it is much easier to prevent the sewer gas from entering than from leaving the house drains. These drains, like a river, derive their waters from many sources, and bring them together to one outfall. The water from all the sources will run through this, and hence, if there is a daily flow anywhere, it will be here; and consequently here the circumstances will be most favorable for the action of a trap. Besides this, there is no chance of the gases leaking into the house drains through open joints. Hence we see that an efficient trap in the pipe which connects all the house drains with the sewer or cesspool, will completely cut off the house from the sewer.

Fig. 8.



It is difficult to say how it is that such a simple remedy as this has been neglected so long, unless it is that the true nature of the evil has never been clearly apprehended. There is, it is true, something to be said against complicating the drains when they are buried 6 ft. or 8 ft. under the surface, and consequently difficult to get at. And this may have been sufficient to prevent the adoption of the measure so long as it was of doubtful advantage.

A good siphon trap of glazed earthenware, such as that in Fig. 6, would probably answer all purposes in five cases out of six; but there is just the chance that the pipe might run full and suck the trap empty, or that the trap might get blocked with sediment, which would be very awkward.

Now, the plan above recommended and described cures both these failings. It secures the trap from being emptied, and furnishes the means of inspecting it, either to examine its condition or to set it right. And it will now be understood why this peculiar construction is insisted on, and why it is placed in the only connection between the house and the sewer.

Such connections as these should be adopted for all houses having drains from within, whether they are in the town or in the country, whether they drain into a sewer or a cesspool. There will then be no need to have traps within the house, and their riddance will be a great comfort, even if we thereby allow air to enter the house freely from the inlets to the drains. Owing to the friction in the pipes not much will come through, and such as there is can only come from the down spouts or such external connections as there may be on the house side of the trap, and will therefore be harmless, unless it meets with some stagnant sewage in the house drains themselves which ought not to be there. We have seen that trapping the inlets will not stop the air entering the house, while the stagnant contents of the traps will perhaps turn otherwise harmless air into poisonous gas.

If the drains within a house are already well laid, it may not be worth while to disturb these simply to do away with the traps; but where this is not the case, or where after the external trap has been put in there is still annoyance from the drains, then the best plan will be to reduce the whole system of drains as much as possible, as shown in Fig. 8, and do away with all traps except the pan of the closet. And above all things see that the new drains are well laid and keep a register of their position.

The through business over the Union Pacific road, for the first nine months of the present year, exceeds that of the same period last year by over £6,000,000. There has been something of a falling off in tea, hides, leather and general merchandise, but a marked increase in wool, coffee, salmon, wine and flour.

THE SCOPE OF ARCHITECTURAL PRACTICE.*

From "The Building News."

Scientific knowledge has now become a necessity in every artistic and constructive pursuit, and those who aim at a high standard must not lag behind in this respect. The late Professor Whewell, referring to the contrast between theoretical and practical work, said in one of his lectures:—

"Looking at the progress of art and science in past times, we find in general that art has preceded science. Men executed great works before they had a scientific insight into the principles on which the success of their labors was founded. There were good artificers in metal before the principles of chemistry were known. Mighty masses were raised into the air before there was a theory of the mechanical powers. The earlier generations did—the later explained how it had been possible to do so; art was the mother of science—the comely mother of a daughter of far loftier and serener beauty."

"Stimulated by the sight of such massive works of human skill—stimulated still more by the natural working of those powers of man from which such skill had arisen—men were led to seek for science as well as art—for science as the natural complement of art, and fulfilment of the thoughts and hopes which art excites—for science is the fully developed blossom, of which art is the wonderfully involved bud."

In this address I am led in some measure to deviate from what has frequently been customary among those who have from time to time spoken from this chair, and it has been partly because the great works of the past, as well as those of more recent date, have frequently and with great ability been described and criticised, leaving me but little ground to travel, and partly because I feel strongly, that, in the increasing importance of the architectural profession in this country and abroad, we must look for a fuller development of the art and science of the profession in the rising generation of its members.

It is perfectly true that the members of the profession in times past have shown no lack of the genius to invent, the patience to persevere, and the zeal and enthusiasm to overcome all the difficulties which occurred in the execution of their many important works; we know this and we are justly proud of their successes; yet still I feel that as the importance and magnitude of the work is steadily advancing, so will it be necessary for the rising generation of architects to be educated to the evident necessities of the case.

Scientific education is made a special object in all the great schools and colleges on the Continent, and although at the present time many great facilities for scientific study have been opened up in this country, I scarcely think that the opportunities have been fully appreciated. I do not fear, nor have I ever feared, that the art workers of this country would prove unequal to any demands which may be laid upon them, but if they are to rise to this position, they must not neglect the daily increasing opportunities of scientific information on all subjects connected with their avocation.

Not long since, at an art exhibition, I heard a remark from Lord Granville which exactly illustrates what I wish to convey; he said: "There was an old lady being driven down Piccadilly one day when the thoroughfare was much crowded, and the horses of her carriage, being very spirited, were going along at a quick pace; so she pulled the check string, and said to her coachman, 'John, are you not driving too fast?' John answered, 'There's no fear, ma'am;' to which she replied, 'There you are wrong, John; there may be no danger, but there's a great deal of fear!'"

It is from these considerations that I would urge it as a special duty upon our young members to take good heed that the honorable and high position achieved and maintained by those who have gone before them should not in an age of still greater responsibilities suffer any declension in those who follow.

In order to give a practical turn to these remarks, and to bring them more prominently before the younger members, I would draw a short outline of the nature of such works as usually fall within the scope of architectural practice, or within the customary experience of those engaged in the art of building:

1. Warehouses for the storage of goods.

* An address before the Architectural Society of Liverpool by Mr. T. D. Barry.

2. Public offices, railway stations, and buildings representing commercial enterprise.

3. Mansions and dwelling-houses.

4. Bridges, quay walls, and works where special precautions have to be taken against injury by the action of water.

5. Works of sewerage and other underground constructions.

6. Churches and places of worship, including school buildings.

Of course these form but a very few of the various classes of building, but they are sufficient to point out one important fact, that the choice of materials to be used in these works should be a matter of special consideration, that each class of material should not only be good as to quality, but that it should be suitable to the uses for which it is intended. In the first instance which I have enumerated, where large masses and heavy blocks are employed in the construction, taking, for example, the article of stone, how essential it is to ascertain what quality of stone is best suited to the purpose, and how its structure and beds will prove available for the mode of contruction adopted, and the weight it has to sustain; now, it is in such a case that the knowledge of geology proves of incalculable value to the designer, who will, in addition, if he would master his subject, visit the quarry and make himself acquainted with the strata of the stone, and the frequency or absence of loose veins, or other imperfections.

The same remark will hold good with regard to Nos. 2 and 3, where a more delicate material would be appropriate, and where ornamentation to a greater or less extent would be required.

In the case enumerated under No. 4, a different class of material would have to be selected, with especial reference to the locality in which it is to be used.

Another important material to be understood is brick; its quality, form, strength, weight, powers of absorption, bond and general construction; and here, as regards the quality and fitness of the clay, a knowledge of chemistry is of vast importance; and it is worthy of note that even the clay we trample under our feet cannot be brought into proper and intelligent use without the aid of science. And this, I think, gives our young members a useful lesson, namely, that they may never be ashamed to soil their hands in seeking full information, as science without practical experiment will be quite as worthless as practice without scientific knowledge. The kid-gloved section of art workers will never soar above mediocrity, if they even reach so far. The taint which the true artist has to shun is not the stain of honest industrious investigation, but the smallest blot upon the escutcheon of his honor and integrity. Mortar is another material requiring special consideration, and this, too, must be chosen with reference to the conditions and position of the structure in which it is to be employed.

In no article of such general use in building is there such inattention manifested as in the making of mortar, and yet the very life of the structure is dependent upon its component parts, quality, and mode of mixture.

The nature of the lime, the proper quantity of sand suitable to its quality, the removal of the unburnt core, the regulation of the quantity made so as to accord with the day's work, are all to be taken into consideration.

Cement is another material which should be carefully considered, being now so extensively used in our most important works. In this article there is very great competition, and, in consequence, many and serious adulterations take place, so that a proper test should in all cases be applied, so as to prove its strength, the time it takes to set, and the best mode of mixing.

Concrete, also, is one of those artificial foundations which it is necessary to understand thoroughly, both in its preparation and mode of laying down; and when properly deposited it forms a most valuable and immovable support where the natural soil will not afford it, and not unfrequently when the excavated ground is too soft to be trusted, a good foundation of this material may be obtained by laying it on the surface, taking advantage of the grass where no better support can be found.

Puddle is another valuable material, requiring care and investigation as to its properties and mode of preparation. In all cases where the action of water has to be guarded against, it is a necessity, and this being the case, it is worthy of our careful attention.

In cases of underground stories in houses, rain-water tanks, trenches formed for the exclusion of running springs, etc., all efficiency depends upon the perfect preparation

of the clay, and the mode in which it is deposited and amalgamated. And here I may just observe that in all house drainage, where health and comfort are the chief objects, every drain pipe should not only be jointed, but also entirely surrounded with a thick coating of puddle, which effectually seals the drain, and preserves the soil from contamination by leakage, which under any other circumstances will take place, even through the pipe itself.

The various qualities of timber are, of course, a most necessary study: their structure, bearing properties, fitness for external and internal work, and another element, which is, I fear, too often overlooked, their effect in construction, by adopting variety of color in the material itself. Often, I think, we miss the mark in seeking for artificial color and decoration, while we neglect that ready, inexpensive, and enduring variety which can be applied in the construction itself.

These remarks will apply with equal force to other materials, such as brick and stone. If a suitable color cannot be found in the material, let us not attempt to color it. If bricks cannot be found red enough to produce the strong contrasts at which many architects are now aiming, let us learn to discard rather than to paint them. As I said before, our wisdom consists in accommodating the design to the materials we have at our command; and I am persuaded that the more we keep this point in view the nearer will be our approach to true artistic feeling.

When we see men painting the bricks on the outside of a church tower, inflaming the surface here and there with an artificial color which can only endure for a year or two, and can never be renewed after the scaffolding has been removed, it is almost time to speak out for our churches. When we see stone surfaces and mouldings, aye even carved work itself, coated over with a dark green ground, and afterwards floriated or bescrolled with misshapen figures, we sigh for a spot on which our aching eyes can rest, some quiescent surface which is a necessary element in every true artistic effect.

If we want color in our churches let us have good stained glass, and this will impart all the color that we need for our stonework.

Let us decorate our roofs and ceilings if we will, but let us spare our walls, and most of all our mouldings and carved work, so peculiarly intended, in their form and combination, to produce an effect of light and shade, which by the introduction of color we entirely sweep away.

THAN her steel works Pittsburg has nothing of which to be more proud. Their product is equal to the best made in England, and is successfully used for every purpose for which steel is employed. Among the leading establishments of this kind tn our city is that of Singer, Nimick & Co., which was established as far back as 1848. This concern is now being enlarged by the addition of two new buildings to the already extensive works. In one of these a 20-in. train is to be placed, which is to be used for the manufacture of cross-cut, gang and rip saws. The other building is to be used for a melting house for cast steel. The furnaces are to be heated by gas, manufactured on the premises. This firm have also a Siemens furnace for the manufacture of homogeneous steel. This is a bold innovation on the old way of making steel, but after a severe test it is found to be a grand success. About 6½ tons is the usual average of a single melt, and its capacity can be doubled at once, if needed. This steel is used almost exclusively in the manufacture of boiler plates, and every plate is tested before it leaves the works.

THE Michigan Central Railroad Company are preparing plans for the erection of new car-shops at Grand Trunk Junction, near Detroit. The paint-shop will be over 700 ft. in length. The setting-up shop will be in the form of a half circle, and will contain 22 tracks and accommsdate 44 freight cars at once. The Company own 90 acres of land at the locality referred to. The same Company are also erecting extensive machine shops at Jackson, Michigan.

THE railroad facilities of Iowa are in no way commensurate with the demands. They can not get the products away as fast as wanted. Every road in the State is crowded to its utmost capacity.

ON CONCRETE BUILDING.*

By JAMES H. OWEN, M. A.

From "The Building News."

MATERIALS.

One-half measure of Portland cement; ½ measure of air-slacked lime, sifted through a fine sieve, mixed together dry. Seven measures of sand and gravel, if possible, of all degrees of fineness, from peas to large eggs, or stones broken to pass through a 2-in. ring—the finer should just fill the intervals of the coarser materials. Then all to be mixed together dry, and measured. The mixture of cement and lime to be then added, and mixed dry, and the whole tempered with as little water as possible; any more than will just moisten the whole is in excess. The most convenient mode of mixing is to prepare a sufficiently large mortar-board, say 5 ft. by 10 ft.; at one end form a shallow box, with three fixed sides, the fourth side next the middle of the board movable. The sides to be as many inches deep as the concrete is to contain measures of material—if 1 to 7, it should be 8 in. deep. At 7 in. from the bottom fix a lath all round the three fixed sides. In using, the ready mixed sand and shingle should be thrown into the box up to the level of the lath gauge, the surface should be levelled and struck with a straight edge resting on the top of the gauge, the cement and lime should then be added, and the surface struck also. It is plain that by this means the materials and measures in the exact proportions directed to be used are attained. The movable side should then be withdrawn (this side can be fixed in its place when required like the tail-board of a cart), and the whole mass well mixed together. The best tool for this purpose is a long-handled rake like a four-pronged fork, with the prongs bent down about 4 in. When the mixing is complete, water should be added gradually, not thrown on in quantity, while the heap is still being turned, until the whole is sufficiently moistened, when it should be at once carried away to the work. Where practicable, it is desirable that the mixing should take place under cover.

It must be constantly borne in mind that by rightly using concrete we ought to get, as the result of the operations, a continuous slab, without joints, and of equable strength in every direction, and not admitting of any motion except as the result of fracture of the mass. In all ordinary brick or stone building the several parts are joined together by material of inferior strength, and the parts are capable of motion whenever a local strain is applied, the pressure resulting from which exceeds the resisting power of the mortar. This should not be the case in concrete building. With concrete, the whole wall from end to end, and from top to bottom, should form one continuous slab of artificial stone; and to attain this, not merely must each course be continuous in itself (for obvious reasons the work must be carried up in courses), but it must be attached to—cemented firmly to—the courses above and below it; and to effect this it is only necessary to leave rough surfaces, and to take care not to add any fresh concrete to a dry surface or edge. If any previously laid stuff has dried, either in the same or in a lower course, moisten it, not to excess, before adding fresh concrete. For this purpose an ordinary garden watering-pot, with a fine rose, will be the most convenient tool.

It is plain from what has been stated that a foundation of concrete may be of much less bulk than one of masonry or brickwork. I am inclined to think that the accompanying section would be found quite sufficient for all ordinary soils. These dimensions seem very small; but considering that a 4-ton railway engine, travelling at 40 or 50 miles an hour, and therefore acting with an impact infinitely exceeding the dead weight of the wall of any ordinary house, is borne by a sleeper 9 in. wide, resting on about 9 in. of ballast, there seems every reason to believe that such a footing as is shown on the sketches would be ample. To take another illustration—a man of average weight, say 13 stone, is able, with Indian snow-shoes on, which each would be under two superficial feet in area, to stand on and walk over the surface of snow without sinking to any extent. The weight of a concrete wall 30 ft. high and 12 in. thick would be nearly three times the weight of the man, but the solidity or power of resistance to pressure of any ordinary soil in foundations is infinitely greater than that of snow. In wet or marshy ground I would recommend that

* Read before the Architectural Association of Ireland.

the breadth of the footing at top should be increased by one-fourth, one-third, or one-half, even up to doubling it, forming the sides to the same batter of 1 to 4, but without going deeper, unless it be found, on making trial, that a reasonbly good foundation can be got at a moderate depth, in which case an ordinary footing should be laid on the firm stratum, and the wall commenced at its finished thickness so much lower down.

The most embarrassing site of all to build on is when one portion is soft and others hard and solid. The best plan is not to build on such a site at all; but if it must be done, I would recommend to reduce the footing on the hard ground down to having hardly any, or even no offset at all, and largely increasing the breadth of footing over the soft parts, so as to approximate as nearly as possible to an equal subsidence over the whole area. No rule or measure can be laid down as to the extent to which this should be done; we can only get a rough idea of the variation in quality from the different penetrations of a bar driven with about the same force into both sorts of soil; but where such differences exist, I think it would not be a bad plan to dig, in the soft places, a trench below the level of the intended concrete footing and of about 2 ft. greater width, and fill it in with gravel without lime or cement, and level it to form a bed for the concrete footing. The additional resisting power would be nearly if not quite equal to that of the same amount of concrete.

It may not be amiss to give here an extract from Viollet le Duc, describing the foundations of the great Cathedral at Amiens, which he had an opportunity of examining down to the very bottom. He describes them as consisting "of a layer of brick earth 16 in. thick placed over the virgin clay; next is a bed of concrete 16 in. thick; next fourteen courses of from 12 in. to 16 in. in thickness each, of rough blocks of a sort of chalk, full of flint and very hard, which comes out in large masses; above this are one course of coursing stone and then courses of freestone under the surface." . . . "Behind the facing of the foundations is a filling of large pieces of flint, of hard chalk, and 'Croissy' stone, grouted ('noye') with a very hard and well-made mortar. On this artificial rock rests this immense cathedral. At Nôtre Dame, in Paris, the foundations are also made with extreme care, faced with strong quarry blocks of great thickness, the whole resting on a good soil, that is on the lower sand of the Seine which is course and of a greenish color. As for the piling which is generally believed to be under the masonry of most of our great cathedrals, we have never found a trace of it." And in a note he adds: "It is the same with this supposed piling under Nôtre Dame de Paris and Nôtre Dame d'Amiens, as with so many other myths current for ages as to the construction of Gothic buildings. It would not be possible to construct a great cathedral on piles. These buildings can be founded only on broad footings; the masses to be borne varying considerably in elevation, the primary condition of stability required a foundation perfectly homogeneous, and capable of continuous resistance under the surface." Without endorsing all that is said as regards piling, in this respect M. Viollet le Duc seems to be led away by the enthusiasm inspired by his subject. You have in the last sentence an exact description of a perfect foundation, and such as you can only be sure of getting by using concrete.

We will turn next to what in ordinary specifications would be comprised under the heads of "Mason, Stonecutter, Bricklayer, and Pavior," and, in substituting cement for each and all of these, we must bear in mind the nature of the material proposed to be used, and the qualities belonging to it which distinguish it from the materials in ordinary use. The only operations it undergoes are mixing the materials and casting them in a mould; for, however it is applied in detail, or whatever we call the machinery employed, it comes practically to this, that it is cast in a mould (though the moulds differ in some respects from those in ordinary use for other materials), and when so cast the whole mass is homogeneous without joints, of great cohesive strength, and impervious to moisture. We shall never rightly appreciate concrete and the mode of using it unless we put out of our heads that it is a mixture of cement and gravel, and all associations with ordinary combinations of lime and brick or stone. We shall best realize the work to be done if we fix in our minds the idea of cast iron. Just imagine a sort of iron which can be moulded cold, in a leisurely manner, and which is only about one-twelfth as strong as common iron, and you have then the right sort of ideas with which to begin working in concrete. There is only one other element to

bear in mind, but it is too important not to mention it separately, and it is this—that every other material used in building, except the hard granites and most compact limestones, depreciate with time and exposure, and require an initial excess of material to be used, and all sorts of surface applications, constantly renewed, to preserve them; whereas Portland cement concrete is permanent and durable under all circumstances, and increases rapidly and enormously in strength, and continues to increase—but in a continually diminishing ratio—for as long as observations have up to the present time been made upon it. This is a most important quality, as it enables us to use it with great economy of material, and with the certainty that if it bears the weight imposed on it at first, it will continue not merely to bear it, but will become continually more able to bear it as time elapses.

The first portion of the "mason's" work to be settled is, of course, the walls. For an ordinary two-story house, with walls not exceeding 24 ft. high, 9 in. is quite sufficient thickness. For walls above that height I would recommend that the thickness should be increased by about 3 in. for every 6 ft. added to the height—of course taking advantage of the occurrence of the floors to reduce the thickness, as shown by construction of an ordinary three-story house. As conrete hardly arrives at its initial strength in less than a month from the time of mixing, it is evident that it is very unsafe to fill up the walls to a great height with too great rapidity. I believe that it will be the safest course to build at the rate of only about 3 ft. of height per week, and then let the work rest and consolidate for a week; this would give a rate of building of 6 ft. per month, which at first sight may appear to be slow progress, but considering the great rapidity with which the internal finishing of a concrete house can be carried on, the total time occupied in building would not exceed what would be required with ordinary materials. In building the walls, as in the foundations, care must be taken to moisten the surface of old work before adding fresh concrete; and this, as before stated, is best done by watering through a very fine rose. As a concrete wall is intensely hard, its surface will be subject to damp from condensation. In inferior houses this may probably be met sufficiently by covering the inside surface with very rough mortar plaster, and washing it with two or three coats of thick lime-wash; but for houses of a better class the walls may either be battened or built hollow. If battening be decided on, provision must be made for fixing the battens, as will be described hereafter. If the walls are to be built hollow, the simplest course to adopt is to lay on the footings a series of brick on edges, tailing into the spaces to be filled by the inner and outer concrete walls, and set about 3 ft. apart, and on these to lay a piece of plank in the direction of the length of the wall, tapered on its cross section and notched to pass down an inch or two in the bricks, which it will keep in their places during the operation; the concrete is then filled in and well rammed up to the level of this plank core, after which it is removed and another course of bricks is laid, breaking joint with the previous course, and the operation is repeated. As regards the thickness of these walls, the inner wall should not be less than 4½ in. thick, nor the outer one than 8 in., and of course the concrete must be carried the full thickness of the wall round all openings.

I purposely refrain from attempting any description of the various forms of moulds or machinery for forming concrete walls; each practitioner has his own invention—most of them patented—but one and all answering the old description, "The one is as good as the other, and a great deal better too," if we may judge from the puffing advertisements that meet one on all sides in the professional prints; but if it be desired to act without having recourse to any of these patentees, I would recommend the following course to be adopted: Provide a sufficient number of stakes of squared timber, say 4 in. by 4 in. about 3 ft. long, tapered and sharpened at one end; having excavated the trenches ready for putting in the concrete for the footings, before doing so mark out by lines the thickness of the walls plus twice the thickness of the planking necessary to form the wall-moulds, and drive the prepared stakes into the ground hard enough to keep upright during the filling of the trenches, and at such places, at angles, and along the length as will be convenient for the future uprights to support the planking.

If necessary, the width of the footings may be increased where the stakes occur, in order to surround them with the concrete. When the stakes are withdrawn after the footings are set, there will be a set of sockets

provided, into which posts of the same scantling may be set; these can be easily plumbed, and tied together on top by ropes or bands of iron or strips of timber. Then it is only necessary to slide in planks, and the mould for the wall is complete. To keep the planks apart, cross pieces of the required length can be jammed between them and removed after the intervals between them have been packed with concrete. Such an apparatus can be prepared anywhere, and worked by any one who can use a plumb-rule.

We next come to the formation of the openings. If a mere hole in the wall is intended, a core, solid or hollow, will be inserted of the proper size and at the proper level; and, in building with concrete, every hole most be foreseen and provided for beforehand, whether it be for drains, air, water, or gas-piping, or tubing for bells; after-boring must be avoided as far as possible. For openings intended to be filled in with windows, doors, or grates, frames or moulds must be made of the shape and size of the interior of the opening; these need not be of the whole height, as they can be raised from time to time until the proper height is attained, and in this way one mould would suffice for several openings of different heights, so long as the width and form of head were the same: thus if the windows are segment-headed, and the same width in all the stories, but varying in height—say 7 ft., 6 ft., and 3 ft. 6 in.—if the mould he made to fit the upper 2 ft. of one, it can be used for all; and in the same way with doors—no lintels will be required in building with concrete, because it forms its own lintels, and requires no arch over it. And here let me call your attention to an ancient example of a concrete lintel given by Viollet le Duc in the "Dictionnaire de l'Architecture," article "Béton," p. 206, Vol. II.:—"We see in the castle of the city of Carcassone windows and doors of the end of the eleventh century, the lintels of which, of considerable bearing, are formed of concrete run in a mould. We give a sketch of one of these windows: the lintel *a* is of concrete of extreme hardness, and we have not seen one of them broken by the loading, which, however, is considerable." He adds in a foot-note: "The shaft which divides this window into two parts is of white marble from the Pyrenees, as also are the base and capital; the jambs and second lintel *b* are of green sandstone. The constructors thereby have admitted that a piece of concrete was less fragile than the natural stones, when supported only at its ends, and loaded in the middle. This lintel is only 9.84 in. thick, with a bearing of 3 ft. 7¼ in., and a breadth of about 11.8 in." You will preceive that the floor girders rest immediately on it without any intervening wall-plates. This example is of great importance as giving confidence in the right use of the material.

All frames must be made without joggles, because it is evident that if the horns or joggles are left on they must be bedded in the work as it proceeds, and any after repair would be very difficult.

For fireplaces and chimneys, the breasts should be constructed in the same manner as the ordinary walls. A simple mould of three planks will enable the opening to be formed up to the arch; this and the gathering should be formed in one mould of sheet iron or zinc on a timber frame somewhat similar to those very admirable articles made of terra-cotta, and queerly named "oncomes" by the Scotch manufacturers. A timber drum about 2 ft. long, with a handle for drawing it up, will serve as core to the flues, which cannot by this means of building be left foul or gathered too quickly. Almost any amount of corbelling can be done most easily and economically with concrete, and fireplaces can be put in positions that would be considered impossible in ordinary building; flues can be left for ventilation also with great ease. The only precaution which I would recommend is not to carry ventilation flues up to the top of a chimney-shaft, but to give them outlet just over the roof at the bottom of the shaft, so as to avoid return smoke, the nuisance of which is a very dear price to pay for ventilation. Outside the roof, preparation should be made for fixing the flashings by bedding thin laths of deal in the course they are intended to take, which, when withdrawn, will leave a groove into which the lead can be pinned. All offsets and the top of the shafts must be left rough and afterwards moistened and finished with fine cement mortar, well trowelled and sloped to throw off the wet. I would recommend also to bed on top of each flue a length of flue-lining, projecting about 4 in.—it will assist the draught and save the arrises round the flue from wear and tear.

No wall-plates, tassels, bond-timber, or any such thing, must be bedded in concrete

walls. The plates for the roof will be bedded on the walls, and all those for carrying floors on corbel courses of concrete, which can be easily formed by attaching a mould of the shape and size required to the face of the wall at the proper height, and can be afterwards covered with plaster so as to form a cornice to the room. For hearths, the joists should be trimmed to the size required. A strong fillet of deal should be fixed against the inside face of the joists, with rough boarding thereon sufficient to bear the weight of the concrete until it sets. The box thus formed should then be filled in with concrete extending to the back of the fireplace; and by finishing the surface with fine stuff, well trowelled on the face, you will have trimmer-arch, hearth, and back hearth all in one solid block, and perfect security against fire. This operation had better not be done until the floors are laid. From what has been stated, there will be no difficulty in constructing any portion of a building which may not have been described, bearing in mind that any width of opening can be spanned without lintel or iron arch-bar, and that all idea of spreading may be left out of the calculation of the jambs; it is only necessary to give them mass enough to sustain the load pressing vertically upon them. There is no lateral pressure, provided the mould is kept up until the concrete has consolidated. In all building operations over-haste is the evil of the day, and this is specially dangerous in concrete building.

It may be convenient now, before passing to what is usually cut-stone work, to describe the nature of the materials. For the sake of economy, I have recommended a mixture of air-slacked lime with the cement in the foundations, but in the shaft walls cement only should be used. It should weigh not less than 112 lbs. to the imperial bushel; if much lighter than this, it cannot be depended on, and should be rejected. It will be safest, I think, to adhere, for the body of the work, to the same proportions as given for the concrete in the foundations—1 to 7; but finer stuff should be used for some purposes: thus for forming the quoins, the angles of jambs and arches, a mixture of 1 to 3 or 4 should be used, rejecting the coarser materials. This fine stuff will take a sharp arris from the mould, and retain it, and save a good deal of time in the after-finishing. All corbelling, and wherever great strength is required, should be done with even finer stuff, say 1 to 2, as the strength of the mass decreases very rapidly with the increase of the quantity of sand or gravel, and for this reason I would not recommend the common practice of inserting in the heart of a concrete wall lumps of stone; it should never be done where strength and coherence are of importance.

Now as regards the cut-stone work. Suppose that a hall is to have a floor not boarded, and steps that would be stone ordinarily, the proper course will be to fill to within 3 in. of the finished level with any dry rubbish, level the surface, fill in with concrete and float it over to the required level, and finish the surface with fine stuff, placed in a thin coat over the moistened surface of the coarse concrete, and continually trowelled until it is quite smooth and hard. The steps must be formed one by one, by fixing a board of the required height where the face of the riser will come, filling with fine stuff against the face of the board, and hearting with coarse stuff; the upper surface would be finished with the floor. If a flight of steps is required, they may be constructed with perfect safety, attached to the wall only on one side, if required, and of any projection, varying the thickness of material in proportion to the work to be done. The steps should be formed simultaneously with the walls, but of the finer material, say 1 to 2; the mould would be constructed of a soffit of timber planking, securely fixed, as it will have great weight to bear, a timber string at the end of the intended projection, and a movable board of the size of the face of the riser. This movable board will be fixed in its place for each step in succession, from the bottom to the top, each in turn being the foundation of, and incorporated with, its successor, so that the final result is not so much a set of individual steps, but one continuous mass with steps notched out of it. There is no difficulty, except in the case of winders, where the moulds of the soffits will be some expense and trouble, but of course infinitely less than carving out each separate stone. The soffit mould in this case may either be made of very thin boards bent to the shape, or a rough stage can be erected and a solid core formed by building with half-mortared rubble up to the shape, and smoothing over with mortar. By this means great accuracy can be attained, and a surface of paper spread over the plaster will prevent its adhering to the concrete, al-

though it would be no great matter if it did, as the soft mortar could be very easily removed.

As regards window sills, it may be asked, Why have them at all? But as this may be considered an unsatisfactory mode of getting rid of the subject, it may be as well to provide for them. In building the walls, the bottom of the opening left for the window should correspond with the bottom of the sill; and in proceeding to form the sill, a board should be fixed so as to form the rim of the inside face, and a mould should be made in the form of a box with a bottom and one side and two ends; on the bottom a fillet should be fixed to form the throating. The box, when fixed in its place, would be filled, and the upper surface formed by drawing a mould formed to the shape along its length just as an ordinary cornice. All cornices, eave, string, and barge courses would be treated in a similar manner; but it should be matter of consideration whether the finishing of all continuous moulded faces would not be executed more cheaply if run in the ordinary way than by casting in a continuous mould.

In building the walls, projecting corbel courses have been left all round them. On them the tassels will be laid, and the joists on the tassels. On the upper surface of the joists I would suggest that a fillet should be fixed of the same thickness as the floor, and that then a skirting of cement should be run round each floor. My reason for this is, that it obviates the necessity for inserting plugs for fixing timber sheeting. The inner face of the walls may be either skimmed over with lime-putty or white-washed; the outer face coated with a very thin coat of fine cement, or tinted with a cement-wash; the ceilings and floors would be treated in the ordinary way.

As regards the mode of roofing, there is no necessity for any variation from the ordinary mode; but if it is desired to have a very cheap form of roof, I would recommend the following, the description of which I extract from a treatise on Portland Cement by A. Lipowitz:—

1. The inclination of the framework of the roof (which must have an even surface) should be at the rate of $\frac{1}{2}$ or $\frac{3}{4}$ in. per ft. The rafters or joists should not be more than 2 ft. 3 in. apart, so as to give sufficient strength. Boards of 1 in. or $1\frac{1}{4}$ in. are fastened on the rafters, and should be rebated. These are then covered with a layer of sand $\frac{1}{4}$ in. or $\frac{1}{2}$ in. thick, to produce an even surface.

2. Strong brown paper, in continuous rolls, and as broad as possible, is then laid upon it, so that each length overlaps the other by about 4 in. When the whole or a large part has thus been covered with paper, the mixture is put into a cauldron, in the proportion of 100 lbs. of tar to 180 lbs. of Portland cement. Care must be taken to heat the tar gently, and to mix the cement with it gradually, in order to prevent its boiling over. This mixture of tar and cement must then be laid as hot as possible on the paper with a tar brush. The next layer of paper is then laid on it, and smoothed with a light wooden roller. In this way the whole roof must be covered. In order to break the joints of the paper, begin the second layer with half the breadth, and proceed as before. The third and fourth layers are in like manner laid with alternate layers of the mixed cement and tar and brown paper. The last layer must be carefully covered with cement, and then strewed with sifted ashes to the thickness of $\frac{1}{4}$ in. Next to the gutter is a board, covered with zinc, and projecting about 2 in. It should be laid on after the second layer has been completed, so as to be covered by the third and fourth. If there are any chimneys projecting through the roof, they should be surrounded with zinc immediately after the first layer has been finished, and before the gravel is strewed upon it. This zinc should rise 6 in. up the sides of the chimneys, and 3 in. upon the roof; the upper edges should be bent, so as to be let into the joints of the brickwork, where they should be carefully fixed with cement.

3. The whole is then finished with a coating of sifted gravel, containing about one-third of dry loam, truly levelled with rakes and scrapers. This work should not be attempted in rainy or frosty weather.

The workmen should wear very light boots, or, better still, none at all, and should always stand on thin boards when working at the roof.

The advantages of this system of roofing are:—

1. A smaller quantity of wood is used.

2. The roof, being flat, gives more room in the upper floors of the house.

3. It is more convenient for constructing garrets.

4. Protection from external fire, and affords easy access to firemen.

5. If properly constructed, these roofs never require repair.

Several roofs at Herschberg, in the Reisengebirge, constructed on this principle, are now 22 years old, and have never been repaired.

A square foot of this roofing, without the roofing and including the labor, costs about 1½d., and Mr. C. Purkart, in Töplitz, guarantees roofs made under his superintendence.

I have tried this mode of roofing myself, and have every reason to be satisfied with it. It is, of course, much cheaper than the ordinary roof.

The imaginary house is now floored and roofed, but it still remains to fit it with doors, windows, grates, and chimney-pieces, shelving, rails for hanging up clothes, and the innumerable host of things comprehended under the title of fittings. All these must be carefully borne in mind, and provided for beforehand. The walls are like cast iron; they do not admit of the rough and ready driving in of plugs wherever a carpenter fancies—for preference into a flue, if it is at all possible to do so. These walls can only be pierced with great difficulty; the place of all those things must be fixed beforehand, and, while the walls are in building, swallow-tailed plugs of dry wood must be built in for the purpose of fixing them; and that there may be no mistake, every bit of carpenters' and joiners' work should be delivered on the ground before the walls have got many feet high; and if the plugs are placed in the right position, there will be no difficulty in fixing any of the joiners' work, except the door and window frames. These, I think, can only be properly secured by confining them in their places by jamb-linings and architraves which are themselves securely fixed to the plugs.

I think there remains nothing more to add as regards the use of concrete in ordinary houses; one built as I have been describing would be cheap, durable, quieter than one built of brick or stone, safer as regards fire, and free from rats and mice and other vermin. I propose to continue this paper by a consideration of the subject of fire-proof building in general, and the special advantages attending the use of concrete, and the modifications of the ordinary mode of using concrete, and the materials of which it is composed, which should be adopted in fire-proof buildings.

Mr. Carson, in proposing a vote of thanks to Mr. Owen, said that, in his opinion, concrete would never supersede brick, unless, owing to the increasing scarcity of labor, a difficulty might arise in obtaining skilled labor.

Mr. Drew, in seconding the vote of thanks, said that concrete forged itself on us as a material for building, and should be met as such. He said selenitic mortar was preferable to cement concrete, and cheaper. He approved of concrete for a lower class of buildings, such as barns, workmen's houses, etc., but not for the better class of architecture. Although it was claimed for concrete that skilled labor was wholly unnecessary, yet a skilled workman was necessary in order to prepare the moulds and fix the different portions of the work, and that the preparation of the moulds would make it more expensive than masonry.

Mr. Briggs bore witness to the great benefit that accrues from using concrete in foundations.

Mr. Henderson said that he was at present carrying out a building in concrete. He had one skilled carpenter and six laborers, who execute on an average one course of 20 in. each day. The method adopted was by side boards, secured in their places by iron bolts and nuts, the boards being moved upwards, course by course, as the work proceeds. Floors are carried on partitions 6 in. thick; stone corbels checked for tassels are inserted so as to distribute the weight evenly; window and door frames have the joggles left on them, and are set in their place as the work proceeds, and are therefore perfectly immovable. A stream runs convenient to the site, from which coarse and fine shingle is obtained of the relative proportions 5 to 2, which are mixed with 1-7th part of cement. The walls are also packed with stones. He considered that there would be a difficulty in running mouldings, as it would not be easy to fix guides to the mouldings, as nails cannot be driven into the walls. He considered that hollow walls would be better formed by square drums 3 in. apart than by the method described by Mr. Owen. He calculated the cost to be as 75 to 100 between concrete and masonry.

The President, in putting the vote of thanks, said that he had carefully calculated the odds on both sides, and had decided in favor of a good rubble wall, and to avoid concrete as much as possible. As to

studding, he deprecated it completely, being nothing more than a makeshift. He had seen an 18 in. wall in the dampest climate resist the moisture. In foundations the use of concrete is invaluable. He approved very much of the method of having corbel courses to support floors, as no wood should be built in the walls. That after all that had been said in favor of concrete, he thought that the walls bore a small proportion to the whole cost of the building; strike a balance and you will find that brick and mortar will hold its own. How could a cathedral be built in concrete? How would a flying buttress and pinnacles be executed? Concrete destroys color, the very life of a building. He thought, however, that it might be moulded in blocks, and colored, and be used as a substitute for stone.

Mr. Owen, in replying, said he would only recommend concrete for the very humblest class of buildings, and as a means of solving the problem of housing the poorer classes. It is not at all impossible to use concrete in an artistic manner, or to combine it with other materials. It is, in fact, the only fire-proof material. The carriage of cement is the same in all parts of Ireland, and the other materials are to be found everywhere in Ireland. On the whole, he thought for a certain class of work there was no material like concrete.

SHIPS OF WAR.

From "The Engineer."

With the foundering of the Captain one of the most remarkable controversies to be met with in the records of science practically came to an end. For years previously the relative merits and demerits of broadside and turret had been argued with a skill, a pertinacity, and an energy almost without parallel. Men profoundly versed in naval and engineering science ranged themselves on opposite sides; and maintained the superiority of broadside or of turret, as the case might be, with such warmth that what should have been calm discussion now and then degenerated into something not far removed from personal vituperation. The war was carried on in every conceivable way, and at all times and seasons. Battles raged in the council-room of the Admiralty Board, in the smoking-rooms of West-end clubs, in the cabins and ward-rooms of our fleets, within the walls of scientific institutions, in the columns of every newspaper or journal possessing the smallest importance; the scientific men of every nation joined in the discussion; never was any subject so well ventilated as the construction of ships of war. The very complexity of the questions discussed rendered it impossible to avoid the consideration of every detail. In the midst of this war of opinions, our navy was to a great extent reconstructed; finally, the value of Captain Coles' views was crucially tested, and the catastrophe which fairly demolished the advocates of the monitor system as represented by the Captain, at once spread gloom over the country, and terminated, at least for a time, the warfare which had previously been waged with such uncertain results. A few of the advocates of the broadside system fired parting shots at their defeated foes, and these in one or two instances replied with a sullen gun; but from the moment the Captain foundered until the appearance a couple of weeks since in the pages of the "Times" of a letter from Mr. Reed, the construction of our navy had virtually ceased to claim public attention; and the few discussions which now and then arose on the subject lacked vitality, and died out in the easiest fashion imaginable. Mr. Reed has succeeded, however, in once more directing attention to our naval strength; and the attitude assumed by various naval men affords fair promise that we shall during the present winter and the coming spring have the merits and demerits of every possible type of fighting ships very keenly discussed. The battle will no longer be waged, however, between two great parties. On the contrary, it will be fought out between half a dozen parties, each holding that they, and they alone, can give the world *the* fighting ship of the future. In such a discussion it is more than probable that important considerations may be completely forgotten, and we therefore think it may be advisable now, while it is yet time, to try to direct opinion into a channel where it may run with service to the nation. We cannot carry this attempt into practice in any better way than by endeavoring to place a

few important facts concerning the present aspect of the "Ironclad Question" as clearly as possible before our readers.

All competent and sensible authorities now recognize the fact that England's navy ought to consist of three great classes or types of ship. The first is the heavily armored ship, which will discharge the duties formerly performed by ships of the line mounting from 70 to 120 guns. The second class will consist of heavily armed, unarmored ships of extreme speed, intended to police the seas. The third and last class may be termed the floating fort—a species of monitor very heavily plated and heavily armed, intended solely for coast, or, more properly speaking, harbor defence. For convenience we shall speak of this last class first. To all intents and purposes it has no existence with us as yet, although the general characteristics of the type have often been considered and discussed by naval men and engineers. It is, we believe, to this class that the "circular ironclads" of Mr. Reed belong. The harbor defence ship would never go out of sight of land. She would, indeed, rarely leave a port. She would not be required to carry coal for more than 24 hours —say a couple of hundred tons. No difficulty would be met with in making such a fort absolutely impregnable to any gun which it is probable could ever be brought to bear against her sides. As she would not be burthened with stores, coals, water, or provisions to any extent, she could carry armor 24 in. thick if necessary, and mount two, or perhaps four, guns of the heaviest and most powerful kind. Her duties would be confined to the destruction of any enemy's fleet which might have the temerity to approach close to our great ports or harbors. It would not be necessary that she should steam very fast. If the attacking fleet remained, she would destroy it; if the fleet ran away she would not be required to follow. She would discharge the duties of a bull dog in an orchard—the apples would be equally safe whether the bull dog bit a thief or did not. No competent naval architect will see the slightest difficulty in designing and constructing efficient floating forts, because he would simply have to make them big enough to carry guns and armor, and he need not trouble himself about coals, or stores, or rigging, or rolling; nor, indeed, about any of the questions which usually vex the soul of the naval architect who meddles with cold iron.

The construction of the fast unarmored ship is not a very recondite problem. That also is easily solved. Coals take the place of armor, and although much consideration must be given to questions of stability, power of keeping the sea for long periods, etc., it may be accepted as proved that these difficulties can be satisfactorily overcome. A class of objectors exists, however, who maintain that these unarmored ships would be useless, because they would be easily defeated by the first ironclad they encountered. It would be the especial business, however, of the captains of unarmored ships to keep out of the way of ironclads. It was well known in the old days before steamships were invented, that if a frigate was caught by a line-of-battle ship the frigate must surrender, or be sunk without hope of escape; but no one ever argued as a consequence that frigates should not be constructed. On the contrary, they were extremely popular vessels, and the good service which they rendered justified their popularity. Besides, they were scarcely ever caught by a line-of-battle ship. They were much too fast, and their captains were too knowing to fall easily into a trap. The frigates fought among themselves, and the line-of-battle ships among themselves, but on the whole they kept very clear of each other. In the same way the modern frigate, or unarmored corvette, would fight with her equals and let the ironclads alone; but even the ironclads would find that an enemy's ship capable of steaming 17 knots an hour, and mounting a couple of 25-ton guns, would be a very unpleasant companion, and one which it might involve a great expenditure of gunpowder to get rid of. We may, we think, take it as proved that we ought to have plenty of unarmed corvettes, good sailers, and better steamers, wherewith to protect our commerce and destroy that of an enemy.

So far the construction of a fleet is all plain sailing; the moment, however, we approach the heavy ironclad, the ships of the line on which the brunt of England's defence will fall in the hour of need, we are beset with a host of difficulties. We cannot put thicker armor on our ships than they carry now without either increasing their size and cost immensely, or sacrificing coal, and speed, and offensive power. But we shall assume, for the sake of argument, that a new Devastation could be laid down to-morrow, which would be protected by 15 in. of iron instead of 12 in., and we ask

what should we gain? And the answer is, nothing. To all intents and purposes the limit of thickness in armor is very nearly if not quite reached; and yet we have a dozen guns at this moment which would punch the Devastation, or indeed any other ship afloat, with absolute certainty at more than 1,000 yards range. Harbor defence ships can be covered with armor almost *ad libitum*, but it is totally different with sea-going cruisers. With them, as we have said, the maximum thickness of armor has been almost reached. It is difficult to see how any sea-going ship can be made to carry more than a little bit of armor strong enough to defy the 35-ton gun; and even if this were not true, nothing would be gained, because the limit in the power of the gun has not nearly been reached yet. There can be no shadow of doubt but that Colonel Campbell and Mr. Fraser could make 55-ton guns, firing 200 lbs. of powder behind a 1,000 lbs. shot, if they are asked, with just as much ease and certainty as they now make 35-ton guns; and Captain Scott would supply carriages for working such guns without the least difficulty. Such a gun would probably pierce 18 in. armor at over 1,000 yards range without any trouble. But besides the other objections to the use of heavy armor, lies the difficulty of getting it. We do not say that it is impossible to make an armor plate 18 in. thick, but we believe that the work of making such a plate will task all the skill of the best ironmakers in the world, and that it is more than questionable whether the plates when made would be be really much stronger than a 12 in. plate. If a ship is to keep the sea, to be fast, safe, commodious, and handy to any extent, then it may be taken for granted that she can carry no plates more than 12 in. thick, and that the larger portion of her exposed hull must be covered with plating very much thinner than 12 in. But 12 in. plates can be pierced by heavy guns at short ranges; the question therefore arises, are 12 in. plates, which cannot keep shell or shot out, worth having at the great sacrifice which must be made to enable a ship to carry them? Let us see what are the answers to this question.

We have pertinaciously insisted that ships are better without armor than with thin armor, that is to say, armor through which shells can easily be driven—say plates 6 in. to 7 in. thick. But we see reason to modify this opinion when we come to deal with 12 in. plates. In the first place, only very heavy guns can send a shell through 12 in. plates. At this moment there are probably not half a dozen guns afloat in the world which could pierce the Devastation's turrets, except at the very shortest range—100 yards or so. Captain Sherrard Osborn, in a recent letter to the "Times," has, moreover, put forward a somewhat novel argument in favor of even thin armor, which deserves some consideration. It is to the effect that the great thing to be dreaded is the explosion *between decks* of a shell. If the armor is thick enough to sensibly retard the entrance of a shell, then he points out, the force of its explosion will take place to the rear; and although the head will enter, and much damage may be done by splinters, the evil will be as nothing compared with the explosion of an entire shell just at the moment it has got fairly inside the plate. Assuming this view to be correct—and it is a very plausible argument—then it is certain that even against very heavy guns 12 in. armor will do good service, while against light guns light armor may prove useful. As, however, even unarmored ships will carry very heavy guns, our arguments against the use of thin armor remain unshaken; but the 12 in. plates of the Devastation will probably prove useful until a gun much heavier than any we have got is brought against them.

But it does not follow that the 12 in. armor of the Devastation is used to the best advantage. To carry Captain Sherrard Osborn's theory a little further, it is obvious that if the greater portion of the force of the explosion of a shell be expended towards the rear, and that nothing but *mitraille* is left to enter the ship, a comparatively slight second armor plate would suffice to keep out the *mitraille* altogether. For example, if, instead of having 12 in. of iron in a single solid plate, it was disposed in two plates 5 ft. apart, the outer plate 7 in. thick, and the inner plate 5 in. thick, then it is certain that the shell would be broken to pieces on the first plate, and that these pieces could not get through the second plate. It is of the last importance that the Government should test the accuracy of our views—views which we have persistently advocated for some time past—by direct experiment. Nothing can be easier than to place two plates one behind the other, with an interval of 5 ft. or 6 ft. between them,

to fire a shell at these plates, and to mark the result. Noting in the way of timber or concrete should be interposed between the plates, the utmost freedom being left for the dispersion of the effects of the explosion of the shell. The experiment has never been properly tried, probably because there is no doubt that although single 12 in. plate will keep out a *solid shot* of a given weight, two plates 5 in. and 7 in. thick will not keep it out. But naval men are not afraid of the solid shot. What they want is defence against shell. When our views on the value of an air space between the plates are proved by experiment to be correct, then shell will have lost half its terrors, and we shall enter on a new era in the construction of ironclad ships.

THE ASPHALTS.

From the "Journal of the Society of Arts."

(*Continued from page* 82.)

The first specimen of this kind of road was laid down between Bordeaux and Rouen, in the neighborhood of the town of Saumur. A layer of broken stones, such as those used for a macadamized road, was laid down, and over that asphalt broken up small, to the depth of 1½ in., which would appear, to any one well acquainted with the nature of the material, to be an eminently practical method. Experience was, however, to show otherwise. At first the new streets seemed to be a complete success, for the asphalt soon became firm and solid; the stones were crushed down and the malleable asphalt filled up the interstices. The surface yielded to the pressure of the carriage-wheels without cracking, the impression made by each horse or carriage being effaced by the succeeding one, and it did not appear to be affected by summer or winter, least of all by wet, and the softest parts of the road were found most durable. On the strength of this favorable experience, many roads and bridges were covered in the same way, near Saumur, Angers, Tours, and Briare, and on the great bridge over the Loire at Saumur it was found that the two arches which were covered with asphalt were water-tight, whilst the 17 others let the water through, although carefully covered with hydraulic mortar.

In time, however, the drawbacks in this system became apparent. The crushed granite of the macadam substratum, mixed up with the asphalt, destroyed its continuity, and by preventing it from forming an unbroken surface allowed it to be permeated with dirt and water. This method could not be, therefore, said to be satisfactory. The final solution of this problem is due to the engineer, M. A. Merian, of Basle, who conceived the idea of laying down powdered asphalt in a warmed state on the street, and applying a strong pressure, so as to form at once an impermeable elastic surface. He tried the experiment on a part of the high road between Serrieres and Travers, with such success that, in spite of the insufficient foundation on which it was laid, that part of the road has remained unimpaired to this day.

The French engineers soon followed the example of M. Merian, and although they cannot dispute the right of the Swiss to the first invention, yet they may claim for France the honor of having taken the lead in every useful application of asphalt.

In the same year, M. Darcey, Inspector-General of the Ponts-et-Chaussées, published a treatise on the different descriptions of street pavements in London and Paris, in which he advocated the plan of laying the cold asphalt down on the macadam foundation. Under his direction several of the boulevards at Paris were thus paved; but soon the drawbacks to which we have alluded were perceived, and M. Darcey acknowledged the superiority of the compressed hot asphalt powder, which has a tendency to cohere, whilst in the case of the cold broken asphalt, considerable resistance is offered to the union of the abraded particles. In Paris, the hot compressed asphalt was first tried in the Rue Begère, near the Conservatoire de Musique, and its success decided the authorities to pave the Place du Palais Royal in the same way, and subsequently many streets in different parts of Paris, in none of which has the pavement yet had to be renewed. The following is the process of preparing the asphalt pavement, as described by M. Léon Malo:

"The asphalt stone is brought direct from the quarries, and broken up into small

pieces about the size of those used for macadamized roads; it is then heated over a stove, in a drum-shaped iron vessel with feet, till it crumbles into powder; and in order that the powder may not lose its heat, the whole apparatus is conveyed on to the street where it is to be applied. Then a foundation of 'béton' is laid, about 4 in. deep, which may, however, be thicker or thinner, according to the nature of the soil."

On some ground, a road which has been macadamized, for example, the substratum of concrete may even be dispensed with entirely, whilst on a loose soil it may be made as thick as 6 in. When the béton has hardened, and been cleaned, it should be smoothed to the proper curve. The arch of the roadway ought not to be greater than is absolutely necessary to drain off the rain-water, in order that the horses may not slip on the incline at the side. The powdered asphalt is then spread over the surface, to a depth of 16 to 20 in. (according to the amount of traffic it is to bear), and stamped down; a roller of 2,500 to 3,000 kilogrammes weight is then drawn over it, to make the pressure perfectly even. Two hours later the road is ready, and may be opened to carts and carriages. M. Léon Malo's remarks apply exclusively to the Seyssel asphalt, as, at that time, the other companies had not yet embarked in this undertaking, and it was not till 1856 that an amalgamation took place, under the name of "Compagnie Générale des Asphaltes," from the manuscript report of which, in 1869, the writer has gathered the following facts:—

The Company is now in entire possession of the Seyssel works and quarries, and has a capital of 3,500,000 of francs. The works have been erected at Pyrimont, where the Geneva Railway Company have established a special station. Every year about 400,000 cwt. of the mastic and 150,000 cwt. of powder are prepared, and 150 workmen employed. Since that time, however, these figures will doubtless have been much increased, the asphalt roads being more in request. In 1852, 800 metres of road were laid down in Paris; in 1856, 8,000 metres; in 1866, nearly 100,000; and in 1869, 280,000 metres, all principally in the quarters between the Rue de Rivoli and the boulevards, from the Madeleine to the Rue Poissonière.

But even though the Compagnie Générale des Asphaltes took the initiative in extending the use of asphalt for street pavement, yet it seems as if it would have to leave the field to the Val de Travers Company, as the stone from that quarry is superior for the hot compressed roads to that of Seyssel, which contains only 6 to 8 per 100 of bitumen, whilst that of the Val de Travers contains from 11 to 12 per 100, and hence is tougher.

The bituminous fresh-water limestone of Lobsan does not seem to possess enough solidity to be kneaded into a continuous mass without the addition of any other ingredient.

The asphalt stone of Limmer and of Vorwohle also do not appear suitable for this mode of application, the former being too oily and the latter too dry for the necessary toughness to be obtained without melting.

The writer was shown roads paved with the Limmer stone, and with the three kinds of asphalt—the compressed asphalt, the asphalt-macadam, and the asphalt-mastic; of these only the mastic road could be said to be thoroughly successful. Under these circumstances it was only natural that the general attention should be turned to the Val de Travers, and on the 15th December, 1870, the Government of the canton of Neufchâtel granted the concession of these quarries to an English company, entitled the "Neufchâtel Bituminous Rock Company," which devoted itself exclusively to the paving of streets and roads, supplying various local companies with materials for the purpose. Such companies have been formed in Great Britain and Ireland, which requires annually 200,000 to 2,000,000 cwt.; one in North America, with a consumption of 40,000 to 2,000,000 cwt., in South America, with an annual consumption of 40,000 to 600,000; for Austria, Hungary, and Roumania, respectively, with a similar consumption of 40,000 to 600,000 cwt. Similar contracts have been made for Russia, Italy, Holland, Belgium, and Germany.

As a great deal has been said about the danger to the horses on the asphalt roads, it may be as well to give the experience in France in this respect, which applies equally to the three kinds of asphalt roads.

At Lyons, which has long had mastic roads, a number of cavalry horses fell on a street of compressed asphalt. This accident arose from the circumstance that the asphalt had been laid on an old macadam road, and had therefore that considerable arch which is unnecessary and dangerous for the as-

phalt road. The cavalry riding in a long line, those horses near the side of the road slipped on the steep incline.

At Marseilles, where the asphalt roads from the town to the harbor were made with a very gentle curve, there has been no increase in the number of accidents, though the traffic is enormous. A very slight arch of the road is quite sufficient to allow the rain to run off from such a smooth surface.

It is also not advisable to lay the asphalt on any street with a gradient greater than 1 in 60, though in London some streets having a gradient of 1 in 57, and even to 1 in 46, have been covered with asphalt without any apparent danger. It is of course extremely difficult to get any accurate information about the number of accidents on the streets, general vague impressions being worthless; but in Paris the number of horses which were observed to fall in the Rue Neuve des Capucines, during two months were as follows: In the former, which was paved with sandstone, in blocks, from Fontainebleau, one horse in 1,308 fell; on the latter, which was covered with asphalt, one in 1,409, so that the balance was in favor of the asphalt.

In snow or frost asphalt is not so slippery as granite, being in itself warmer, and also more easily warmed by the slightest rays of the sun; hence the ice is more slow in forming, and quicker in melting, than on granite.

It has been proved that the greatest number of accidents to horses happen when the asphalt is not cleaned, for the surface is never muddy or greasy, except with foreign matter, and this ought to be constantly washed off with water, which is plentifully laid on in Paris, and to some degree in London. At any points where this cannot be done, a slight sprinkling of coarse sand will prevent the horses slipping. This is, of course, only a temporary remedy, but valuable in case of emergency. It is one of the great advantages of asphalt, however, that it is so easily and cheaply cleaned.

Considerable alarm has been excited as to the danger of the asphalt taking fire in case of a conflagration. We think, however, that these objections may be met by narrating the following circumstances:

During the Commune in Paris, in 1871, the fires commenced by incendiaries were never known to have been spread by means of the asphalt pavements. In London, experiments were made on this point by heaping wood on the Val de Travers pavement and setting fire to it. When the fire was at its fiercest, the burning embers were raked away, and only a few feeble flames were seen to issue ftom the pavement, and they went out directly of their own accord.

In the stables of the Paris Omnibus Company the corn-loft is immediately over the stables, and in order to protect the corn against the effluvium from the stables the floor of the loft was covered with a thick layer of the asphalt, and in five different conflagrations this floor arrested the course of the flames until help could be procured.

It has also been found that a wooden floor covered with asphalt was entirely protected against a fire which was lighted on the asphalt; for although this material develops a volatile bitumen, which is inflammable, and another part of the bitumen escapes as gas, and burns accordingly, yet the mass of lime and coke which remains is sufficient to protect the wood completely against the flames.

During a conflagration in the works at Seyssel (owing to the bursting of a kettle of boiling tar), the asphalt floor turned the course of the fire, and when the wooden beams and walls were burnt and the asphalt ceiling came down with a crash, it entirely extinguished the flames beneath.

Finally, the conclusions that have been arrived at by the experience in London are:—

1. That the prime cost of the asphalt road is the same as that of a granite pavement.

2. That, with the present prices, the annual cost of maintenance is a trifle greater than the granite.

3. That, at the end of seven to ten years a granite pavement is worn out, whilst the asphalt is still in perfectly good condition.

4. That the asphalt, when taken up, may be always used again for the same purpose or for mastic.

The experience in Paris shows:—

1. The asphalt costs, in the first instance, one-third less than the stone pavement.

2. That the annual cost of maintenance is three-quarters less than that of a macadamized road.

From these facts it will not be difficult for any municipal authorities to deduce the great advantages of the asphalt pavement.

"In the destruction of some ancient fortifications, supposed to have been Roman, near Pyrimont, about 40 years ago, the

stones appeared to have been similarly cemented, and so great was its tenacity, that the works were with great difficulty pulled down, and not without the use of gunpowder. This circumstance led to a singular and important discovery, for the fact of which, as follows, we are indebted to a gentleman named Perrigny, a native of that neighborhood. During the removal of the above ancient remains, it was observed that the cement bore a great resemblance to the asphaltic mass or mountain in the park of Pyrimont, about five miles north of Seyssel. This led several persons present to think of making a similar application of it. Amongst others was a relative of M. Perrigny, whose dwelling on the banks of the Rhone was so very damp that the lower part could not be appropriated to any use whatever. This person considered that its application might succeed in keeping out the wet, every other remedy that he had tried having failed. The experiment was accordingly made, and succeeded beyond his most sanguine expectations. This circumstance, among other early trials of its properties, speedily led to its very general adoption in that vicinity, where the working of this material has become of great importance, and where the presence of the bituminous asphalt is so great as to appear almost inexhaustible; and although but recently worked to any great extent, yet its properties as a cement appear to have been long known. It already constitutes the chief wealth of the country, which was previously half wild."*

* Extract from page 2 of the pamphlet written by F. W. Simms, C. E., on "The Asphalt Mastic or Cement of Seyssel," 1858.

FIRE-PROOF GUNPOWDER MAGAZINES.

From "The Mechanics' Magazine."

Some experiments as to the storage of gunpowder were tried on Wednesday at the Practice Range, Plumstead Marshes, at the instance of the Home Secretary and by permission of the Secretary of State for War. Two or three recent cases have shown the extreme danger to life and property which arises from the storage of gunpowder, especially by retail dealers in towns. With a view to guard against this danger, Messrs. Milner and Co., of Liverpool, have designed a fire-proof safe, to hold small quantities of gunpowder, and the object was to determine how far these miniature magazines will preserve their contents from explosion when exposed to the action of fire.

Four magazines were put to the proof. In form they differ in no respect from any ordinary fire-proof safe. There is no intricate combination of bar and lock, for they need not, of course, be thief-proof, and a burglar would, if he knew it, be hardly likely to break into such a strong box. On the other hand, the walls are of unusual strength. They are formed of 4 in. chambers, between each of which is a stuffing of alum and sawdust. The action of heat dissolves the alum, which contains 52 per cent. of water, and the liquid portion finds its way through small holes in the safe, wetting any loose powder, while that contained in canisters is so protected as to be non-explosive. This, at least, was the theory of the manufacturers. The value of the theory was now to be tested. In the open air, several hundred yards apart, four furnaces had been erected, each 7 ft. in internal diameter, and each heaped up with wood, shavings, coal, and a dash of petroleum to assist ignition. All the magazines were of the same size, and made to hold 100 lbs. of powder loose or in canisters, as it is generally kept by retail dealers and sportsmen; but for the purpose of experiment, it was not necessary to test the magazines with the full quantity. Accordingly a varying weight was placed in each. In No. 1 there were only a few ounces, part being wrapped in bits of paper, each containing "a pinch," and part being in the ordinary tin canisters, each containing about a rifle charge. This magazine was covered up in the furnace, which was fired at 10 A. M. In No. 2 magazine there were placed 10 lbs. of powder, in canisters holding 1 lb. each. In each case, it should be stated, the powder was by different makers, and the canisters used were therefore of no one type. No. 3 magazine held 25 lbs. of loose powder, such as would be used for blasting purposes, contained in a quarter barrel, which was "headed up" and made to stand on two bricks, so as to raise it from any moisture deposited on the floor. Magazine 4 contained 5 lbs. of powder in

canisters, soldered up as they came from the makers, and 5 lbs. loose in a barrel not headed up. In each magazine there were placed two of Negretti and Zambra's self-registering thermometers, with 21 little sticks of alloy (tin and lead), so made under Professor Abel's directions as to melt, according to the varying proportions of the alloy, at varying degrees of temperature, from 340 deg. to 558 deg. Fahr. Gunpowder explodes at a temperature of 560 deg.; but long before this degree of heat was reached, it was expected that the sulphur would be volatilized, when the remaining constituents would be robbed of their chief powers for mischief.

By 11.30 all four furnaces were in a blaze, and there could be no doubt as to the rough reality of the ordeal which the magazines were undergoing. The superintendents of the principal fire brigades in the United Kingdom had been previously asked what length of time a magazine, to be really safe, should be able to resist such a fire as might occur in the shop or warehouse of a retail dealer, or in an ordinary dwelling-house. The longest time assigned by any of these officers in their replies was six hours. Capt. Shaw, and the more experienced men on the ground, were of opinion that this length of time was excessive. However, three of the magazines were constructed on the assumption that if they could resist the fire for six hours they would afford all the protection which was actually necessary. The fourth was of stouter construction than its fellows; it had 6 in. instead of 4 in. chambers, and was made to resist fire from eight to nine hours. As the wall of coal gradually burnt through, and the flames rose high above the buried magazines, there seemed to be no wish among any visitors to disobey the earnest request addressed to them not to approach the furnaces during the progress of the experiments. There was little, indeed, to tempt visitors from cover. The rain poured down incessantly during the part greater of the day, and Plumstead Marshes, at no time very lively, became a dismal swamp indeed. Meanwhile the fires burnt furiously, nursed by the wind and quite unchecked by the rain. It was admitted by most people present that, if the test was severe as to time, the exposure of the magazines to a heat so intense and so continuous during that time was a test severer still.

At last the end came, amid general impatience. At 4 o'clock there had been no explosion anywhere. A few minutes afterwards, Magazine No. 5 was disengaged—no easy task—from the glowing mass around and over it. It was then opened, and its contents were inspected by Major Majendie. One of the thermometers was broken. The other marked 210 deg. Of course none of the rods of alloy were fused. The "pinches" of loose powder were thoroughly wetted, and the paper containing them was pulp. The powder in the canisters came forth unharmed, and its properties were unchanged, portions taken from each canister exploding readily when a spark was applied. The magazine had been sorely tried. In two places the flames had eaten holes through the exterior plate of iron into the first chamber. The outer plate of the door had also slightly bulged, partly, perhaps, from expansion, partly owing to pressure from within—the generated vapor seeking an outlet. But all admitted that the magazine had passed successfully through the fire, and had fulfilled the promise of its makers, that it would not merely during the stipulated time resist fire, but preserve its contents from explosion. The other furnaces were left to burn out, and the magazines will not be drawn and examined until to-day.

ACCOUNT OF SOME EXPERIMENTS ON THE OXIDATION OF IRON.

By PROF. F. GRACE CALVERT, PH. D., F. R. S.

From the "Journal of the Society of Arts."

Some two years since, Sir Charles Fox inquired of me if I could give him the exact composition of iron rust, viz., the oxidation found on the surface of metallic iron. I replied that it was admitted by chemists to be the hydrate of the sesquioxide of iron, containing a trace of ammonia; to this he answered, that he had read several books on the subject, in which the statements referring to it differed, and from recent obser-

vations he had made, he doubted the correctness of the acknowledged composition of rust. He further stated, that if he took a bar of rusted wrought iron and put it into violent vibrations, by applying at one end the fall of a hammer, scales would be separated, which did not appear to him to be the substance I had described.

This conversation induced me to commence a series of experiments, which I shall now detail.

I first carefully analyzed some specimens of iron rust, which were procured as far as possible from any source of contamination. Thus one of these samples was supplied to me by Sir Charles Fox, as taken from the outside of the Conway-bridge, the other secured by myself at Llangollen, North Wales.

These specimens gave the following results when submitted to analysis:

	Conway Bridge.	Llangollen.
Sesquioxide of iron	92.900	93.094
Protoxide of iron	6.177	5.810
Carbonate of iron	0.617	0.605
Carbonate of lime	0.295	0.295
Silica	0.121	0 196
Ammonia	trace	trace
	100.000	100.000

These results clearly show the correctness of Sir Charles Fox's statements, that the composition of the rust of iron is far more complicated than it is stated in our text books. Therefore, the question may be asked, is the oxidation of iron due to the direct action of the atmosphere, or to the decomposition of the aqueous vapor; or does the very small quantity of carbonic acid which it contains determine or intensify the oxidation of metallic iron? To reply to these queries, I have made a long series of experiments, extending over two years, which, I hope, will tend to throw some light on this very important question; and, although it appeared to me an easy matter to solve, still I have had many difficulties to overcome, which will be described as they occurred in the course of my investigation.

The first series of experiments consisted in placing crinoline and steel wires, very carefully cleaned, in tubes containing pure, dry, or moist oxygen; and in another series of tubes, containing the same gases, was added 1 per cent. of carbonic acid or a trace of ammonia.

Before describing the facts observed, I must state that the oxygen was prepared from pure chlorate of potash, mixed with a little binoxide of manganese, and the gas obtained passed through several feet of U-tubes filled with glass moistened with sulphuric acid and caustic potash. The carbonic acid was purified by washing it with water and passing it through U-tubes containing sulphuric acid. The ammonia was purified by first passing it through a saturated solution of ammonia, and then over caustic lime. These purified gases were then introduced into tubes having 1 centimetre diameter and 30 centimetres in length, which had been previously filled with dry mercury, and containing an iron blade, to the bottom of which had been fixed a small mass of gutta-percha, so as to isolate the iron from the mercury, and prevent galvanic currents.

The results of the above experiments were so unsatisfactory that I was led to infer that I had overlooked some source of error; and it was so; small globules of mercury having adhered to the perfectly polished surfaces of the iron, had become centres of galvanic action, determining the oxidation on the blades, and thus rendering the series of experiments discordant.

To overcome this source of error, cleaned blades of steel and iron, having a gutta-percha mass at one end, were introduced into similar tubes to those employed in the previous experiments, and were placed over a mercury trough; the atmospheric air was displaced by a current of pure oxygen conducted to the top of the experimental tube, and it was then easy to introduce into them traces of moisture, carbonic acid, and ammonia. After a period of 4 months the blades of iron so exposed gave the following results:

Dry oxygen	No oxidation.
Damp oxygen	In 3 experiments; only 1 blade slightly oxidized.
Dry carbonic acid	No oxidation.
Damp carbonic acid	Slight appearance of a white precipitate on the surface of the iron, found to be carbonate of iron; 2 only out of 6 experiments did not give this result.
Dry carbonic acid and oxygen	No oxidation.
Damp oxygen and carbonic acid	Oxidation most rapid, a few hours being sufficient; the blade assumed a dark green color, which then turned brown ochre.
Dry oxygen and ammonia	No oxidation.
Damp oxygen and ammonia	No oxidation.

The above results prove that, under the conditions described, pure and dry oxygen

does not determine the oxidation of iron; that moist oxygen has only a feeble action; dry or moist pure carbonic acid has no action, but that oxygen containing traces of carbonic acid acts most rapidly on iron, giving rise to protoxide of iron, then to carbonate of the same oxide, and lastly to a mixture of saline oxide and hydrate of sesquioxide.

As these facts tend to show that carbonic acid is the agent which determines the oxidation of iron, I am justified in assuming that it is the presence of carbonic acid in the atmosphere, and not its oxygen or aqueous vapor, which determines the oxidation of iron in common air.* Although this statement may be objected to at first sight, on the ground of the small amount of carbonic acid gas existing in the atmosphere, still we must bear in mind that a piece of iron, when exposed to its influences, comes in contact with large quantities of carbonic acid during 24 hours.

These results appeared so interesting, that I decided to institute several series of experiments.

First Series.—Perfectly cleaned blades of iron placed in bottles, filled with ordinary Manchester water, were rapidly covered with rust, whilst similar blades, placed in the same water previously deprived of air and carbonic acid by boiling, remained free from rust for a period of four weeks; thus proving that oxygen and carbonic acid are necessary for the production of oxide of iron in presence of water.

Second Series.—Into bottles filled with some pure distilled water (which had been boiled and then allowed to cool in corked flasks) blades of iron were introduced, and a part of the water in the bottles was displaced by common air, pure oxygen, or carbonic-acid gas; but the results were unsatisfactory. I then decided to keep the upper part of the blade dry; to effect this, clean blades of crinoline wire were introduced into bottles containing pure oxygen, and then boiled and cooled distilled water was introduced by means of an aspirator, until only half the blades were immersed in the water. By this method I was enabled to ascertain the comparative degree of oxidation of that part of the blade dipping in the water, and the results observed were as follows:

The section of the blades out of the water remained bright for several days, whilst that in the water became attacked in about 6 or 12 hours; and the deposit increased so quickly that after 2 or 3 days, the blade was entirely covered with an ochre deposit of the hydrated sesquioxide of iron. This rapid oxidation of iron under these circumstances appeared to me to be entirely due to a galvanic current; for the oxide was deposited in two separate columns which left the outside edges of the blade perfectly bright as well as the centre of it, each separate column apparently representing the poles of a battery. In fact the production of this precipitate was so rapid that, after a short time, a considerable amount was found as a deposit in the bottle.

To be certain that the oxidation of the immersed portion of the blade was not due to the fixation of oxygen dissolved in the fluid, but to the decomposition of water through a galvanic current, I examined the gaseous mixtures existing in the upper part of the bottle, and found hydrogen in large quantities, thus proving that the water had been decomposed, its oxygen being fixed by the iron, whilst the hydrogen was liberated.

ACTION OF OXYGEN-CARBONIC ACID ON IRON IN PRESENCE OF WATER.

To ascertain the influence which carbonic acid exerts on the oxidation of iron, I prepared mixtures of oxygen and carbonic acid in the following proportions:

25	of oxygen to	75	of carbonic acid.
50	"	50	"
75	"	25	"
84	"	16	"
88	"	12	"

Having introduced iron blades and the above gaseous mixtures into bottles, they were inverted over water, so that their necks dipped into this fluid; when half the gaseous mixture had been displaced by aspiration, as in the previous experiments, the following results were obtained, viz., whilst that portion of the blade standing out of the water in the previous experiments remained for weeks unoxidized, in this series the same section of the blade assumed rapidly a dark color, which became afterwards of a dark brown. This change of color was no doubt due, first, to the formation of carbonate of the protoxide of iron, mixed with carbon existing in the iron, and then the excess of oxygen in the mixture converted

* These results prove the statement of Bonsdorff (see Gmelin, vol. v. p. 185), that carbonic acid has no action on iron, is incorrect.

the carbonate into magnetic or saline oxide of iron, with a little sesquioxide of iron. Whilst these phenomena were proceeding with that portion of the blade exposed to the gaseous atmosphere, the one dipping into the aqueous solution was observed to lose its brilliant and metallic lustre in a few minutes, presenting a black appearance, which became, at the end of three hours, of a dark greenish hue, due to the formation of similar compounds as those above described.

In all these experiments the water became not only turbid after a short time, but on the surface of the same floated a considerable amount of magnetic oxide and carbonate of the protoxide of iron, and which varied in quantity according to the relative proportions of oxygen and carbonic acid employed. This series of experiments confirms again the previous ones, that carbonic acid is a most active agent in determining the oxidation of iron.*

ACTION OF CARBONIC ACID ON IRON IN PRESENCE OF WATER.

Having studied the action of oxygen, and of carbonic acid and oxygen, on iron in the presence of water, I was desirous of ascertaining what would be the action of carbonic acid and water. I operated in a similar manner as in the previous experiments, and observed that the blades in the gaseous mixtures had assumed a dark grey appearance; that in the liquid was black, the carbon having been rendered perceptible by the iron having been dissolved as carbonate of protoxide of iron, soluble in the excess of the carbonic acid. After a few days, a perfectly white deposit was formed on the edge of the water, which gradually increased, and became so abundant that some fell to the bottom of the vessel. Water had been decomposed and hydrogen liberated.

I again made another experiment, which further illustrates that carbonic acid is the real determining agent of the oxidation of iron. Thus, a blade of steel placed in pure water, which had previously been deprived of all gaseous mixtures by long boiling, and then allowed to cool, the metal remains bright for several days, and when any signs of oxidation appeared, it was only on a few parts of the blade. The careful examination of this fact led me to infer that the limited action which had taken place might be attributed to traces of impurity in the iron; and this view was supported by the previous observations described, on the influence which minute globules of mercury exert on the oxidation of iron, as well as the known influence which a few thousandths of antimony, platinum, tungsten, sulphur, phosphorus, etc., impart to iron; and, again, the facts I published a few years ago, that by covering the $\frac{1}{100}$ part of a blade of iron with zinc, the whole of the blade is prevented from rusting when plunged in soft or sea water; whilst platinum, under the same circumstances, promotes, in a marked degree, the oxidation of iron. Therefore, if a minute quantity of a substance modifies the properties of iron so as to facilitate or retard its oxidation, we may, I think, fairly assume that any impurity in the purest steel (watch springs) may give rise to the few specks of oxide which were observed in the steel placed in boiled distilled water.

Whilst I was engaged in the above experiments, it occurred to me that it might be useful to make a series with the view of throwing light, if possible, on a fact stated by Berzelius, and well known to alkali and soap manufacturers, viz., that caustic alkalies have the property, even when dilute, of preventing the oxidation of iron.

Do the alkalies possess the curious property of rendering the iron "passive," or, as Berzelius has supposed, is the iron in a negative electrical condition? This is a very difficult question to solve. From many observations I have made, I am led to believe that the iron is in a passive state; and this opinion is based, not only on the known data that a blade of iron is not attacked by strong nitric acid, and that we have no electrical current, if one fluid and one metal are brought in contact, whilst if two fluids and a metal, or two metals and one fluid, are employed, a galvanic current is generated. My experiments show that not only caustic alkalies possess this peculiar property, but also their carbonates and bi-carbonates; and I hope that the following experiments will throw some light on this point. A blade of polished iron was dipped into a solution of caustic soda, and at each end of the blade was attached a wire communicating with a galvano-multiplicator, and no galvanic current was generated; and, again, when blades of perfectly polished hoop iron were placed in bottles half filled with solutions of caustic alkali, carbonates, and bicarbonates, con-

* The composition of the various deposits above described was not assumed, but was determined by careful analysis.

taining from 1 to 5 per cent. of these compounds, and only a part of each blade was immersed in the solution, the other parts being exposed to atmospheric air enclosed in the stoppered bottles, the results were that, after 3 months, neither that portion of the blade dipping in the liquid, nor that in the atmosphere, was in any way rusted in the solutions containing 5 per cent. of alkali; and in the experiments with 1 to 2½ per cent., only part of the blades out of the water were slightly oxidized.

I was much surprised to find that the carbonates and bicarbonates of the alkalies acted in the same manner as their hydrates in preventing the oxidation of iron, not only on that part of the blade immersed in the solutions, but also on that which was exposed to a damp atmosphere of common air. Previously to obtaining these results, I was inclined to believe that caustic alkalies prevented the oxidation of iron by absorbing the carbonic acid of the atmosphere; but, as carbonates and even bicarbonates act in a similar manner, it is evident that this view of the action was erroneous.

The results above stated not coinciding with those obtained by Payen, and given in Gmelin (vol. v., p. 185), I repeated his experiments and found that the portions of the blades of iron immersed in dilute alkaline solutions, as described by him, are preserved from oxidation, but that the portion out of the liquor becomes covered with oxide, which increases in inverse ratio to the length of the solution, and that when the proportion of 1 part of the alkali to 2,000 parts of water is reached, the oxidation of the iron proceeds rapidly on that part of the place just above the surface of the water.

The series of experiments confirms the opinion already expressed, that the iron exists in a passive condition, and that this condition only attains sufficient power to resist oxidation by atmospheric oxygen when there is 5 per cent. of either hydrate or carbonates of alkalies in solution.

I have repeated also M. Payen's experiments on the preservative action of weak solutions of carbonate of soda, and find that my results do not correspond with his. He states that 1 part of a saturated solution of carbonate, when diluted with 54 parts of water, will preserve iron from rust, while 1 with 59 will not. I find that the iron rusts in both cases, thereby proving that stronger solutions are necessary to prevent oxidation.

I have made many experiments with the view of discovering the cause of this interesting preservative action which alkaline solutions exert on iron, but have failed. Knowing the destructive influence which sea-water has on iron, and the serious injury done on iron ships through the action of bilge-water, a series of experiments were made with sea-water, to which was added such a quantity of caustic soda, or potash, or their carbonates, that, after the salts of lime and magnesia were decomposed, there still remained in the solutions 1 to 5 per cent. of alkalies or the alkaline carbonates; and when iron blades were introduced into such liquids, they gave the same results as when iron had been dipped partially into an alkaline solution of Manchester water. I would propose, in conclusion, that a certain quantity of soda-ash should be introduced from time to time into the bilge water of iron ships, as by so doing a great saving would be effected, as it would prevent the rapid destruction of such ships.

After reading the above paper, Mr. E. Hunt inquired whether I had made experiments to ascertain if the presence of caustic alkalies or their carbonates, when mixed with sugar, prevented the marked action of that substance on iron. Considering this a most important question to determine, as iron ships are rapidly destroyed when used for conveying sugar from the colonies to this country, I instituted the following series of experiments:

Blades of iron were partly immersed in a solution containing 10 per cent. of sugar, and in similar solutions to which had been added 2½ to 5 per cent. of caustic and carbonate of soda; after a month the same results were obtained with the saccharine as with the aqueous solutions. But as it would be impracticable to use solutions of caustic or carbonated alkalies in the holds of ships laden with sugar, I thought it therefore advisable to try what might be the influence of zinc, when attached to iron, in preventing its oxidation, and am glad to say that a piece of zinc covering about $\frac{1}{15}$ part of the blade preserves the iron from rusting in that part of the blade immersed in the sugar solution. The use, therefore, of plates of zinc fixed on the sides of an iron vessel, or, perhaps better, the employment of galvanized iron plates in the construction of ships, deserves the attention of shipowners.

RECENT PROGRESS OF THE IRON AND STEEL INDUSTRIES.

By DAVID FORBES, F. R. S., Etc.

From the "Journal of the Iron and Steel Institute."

AUSTRIA.

According to the most recent accounts, the manufacture of iron in this country continues progressing steadily, all the works being in full and active operation. The total production of iron ores and cast iron of all kinds, during the years 1869 and 1870, in the Austrian Empire, including Hungary, is reported to have been as follows:

	1869.		1870.		Increase.
	Viennese centners.	English tons.	Viennese centners.	English tons.	English tons.
Iron ore extracted	12,286,664	680,606	14,913,407	821,901	141,295
Cast iron produced	4,965,544	273,725	5,024,827	276,982	3,257

A. Kerpely, the professor of iron metallurgy in the Royal Mining Academy of Schemnitz, in Hungary, whose excellent reports on the progress of iron smelting have been on several occasions referred to, has just published a work on the present condition and future prospects of the iron manufacture in Hungary. As there are more than 150 iron works so treated, some idea may be formed of the time and labor which the professor has devoted to this task.

BELGIUM.

Every branch of the iron trade of Belgium appears to be in a most prosperous condition, and since many years there has never been so much activity displayed, nor have quotations been so high as at present. It has been found impossible to keep pace with the orders which have flowed in from all sides, the entire produce of many of the iron works being already engaged for a long time in advance, and contracts have been refused for delivery in the spring of 1873. Prices have advanced still more, owing to the difficulty of procuring a full supply of the raw materials, and many complaints are heard of the deficiency of coke which is now at from 18s. 9d. to 19s. per ton.

The total exportation of Belgian iron last year has increased, the figures being 259,000 tons in 1871, as compared with 250,000 tons in the preceding year. The exportation to Russia had, however, been very much less, and the quantity sent to France and the Netherlands also diminished, being respectively 4,000 and 7,000 tons less in 1871 than in 1870. The following figures show the more important items in the exportation of the last two years:

	1870.	1871.	Increase.	Decrease.
	Tons.	Tons.	Tons.	Tons.
Russia	64,000	22,500	.....	41,500
Zollverein	58,000	96,000	38,000	.....
United States	11,000	18,000	7,000	.....
Austria	1,300	14,000	12,700	.....

The importation of rough pig iron increased last year by about 5 per cent., having risen from 82,000 tons in 1870 to 86,000 tons in 1871, whilst the imports of iron generally, show an increase of about 4½ per cent., principally from England and Sweden, as those from France and the Netherlands had declined.

The total exportation of wrought and cast iron of all kinds, during the month of January, was 14,483 tons, which is an increase of 10,816 tons over January, 1871, but is still 3,162 tons less than in January, 1870, showing that the trade has not even yet attained the high point at which it stood before the war. In value, the exports of rails have increased 558,114 francs, and that of other rolled iron 608,160 francs, beyond that of the corresponding month last year. The importation of cast and wrought iron of all kinds amounted to 8,300½ tons, in the month of January, of which 6,431 tons of pig iron came from England. Of

the iron ore imported, 44,796 tons came from the German Zollverein, and comparing this month in 1872, with the corresponding one in 1871, it will be found that there is an increase in the value of iron minerals imported, of 786,682 francs, and of 418,840 francs in that of the pig and scrap iron.

With respect to steel, Belgium imported in January, this year, 713 tons of cast, bar, sheet, and wire steel, but only exported 16 tons in the same month. Preparations are, however, being made to increase this manufacture very largely, both as regards Bessemer, as well as other qualities of steel; the Martin-Siemens process has recently been introduced at the Sclessin Establishment, where a furnace, constructed under the superintendence of M. Noblet, has just been put into work.

The exportation of steel in bars, which in 1870 only reached 320 tons, increased last year to 4,000 tons, of which 2,200 went to Turkey for railway purposes. To England, Belgium exported last year 653 tons steel, against only 3 tons in 1870, but to France the quantity was even less than before.

The number of workmen employed in some of the principal iron works of the province of Liége, at the commencement of this year, has been reported as follows:

Couthuin Ironworks	62
Laminne, mines and works, Ampsin	600
Dumont frères works, at Schlaigneaux	175
L'Esperance mines and works, at Liége	1,890
Grivegnée " "	1,250
Jemeppe, rolling mills	100
John Cockerill, mines and works, Seraing	3,578
Jowa, Delheid & Co., ironworks, Liége	300
Jupille, rolling mills	150
Ougrée, blast furnaces and works	1,570
Sclessin, mines and works	2,653
Vesdre at Dobbain, blast furnaces	100

The report of M. Emile Laguesse, Ingénieur en chef Directeur des Mines, on the Industrie Minérale et Minéralurgique de la Province de Hainaut, has been forwarded us; it brings us down to the commencement of last year, and from it the following extracts are made: In the year 1870, 94 iron mines, having a mean depth of only 69 ft. from the surface, were in operation in this province, employing 318 workmen and turning out 86,463 tons of raw ironstone, which, when washed, afforded 80,000 tons of clean ore, valued at 610,375 francs, or about £24,000.

The total value of the products of the iron industry of the province of Hainaut for the five years, from 1866 to 1870, is given in francs as follows:

	1866.	1867.	1868.	1869.	1870.
Iron ores	650,480	434,320	284,640	533,960	610,375
Cast and wrought iron	75,317,700	65,084,592	60,854,533	81,067,795	87,944,645

In Luxemburg, the extraction of ironstone from the mines in 1870 amounted to 1,010,000 metrical tons, of which 36.3 per cent. were smelted in the country, 38.4 per cent. sent to Belgium, and the remaining 25.3 per cent. exported to Prussia. With the exception of about from 5 to 6 per cent., the whole of this ironstone was of that kind of pisolitic ironstone called on the continent minette; it is explored by open workings on the very regular and nearly horizontal beds of the calcareous marls in the oolitic formation. This ore costs about 1s. 8d. per ton to extract, and is sold at from 2s. 6d. to 3s. 4d. per ton; but as it contains a considerable amount of phosphorus, it does not produce a good pig iron, and is, in practice, generally used along with an admixture of iron of a better quality to improve it. The entire production of pig iron in Luxemburg in 1870, amounted to 158,000 metrical tons, but as mentioned in the last quarter's report, it is increasing so very rapidly, that it is estimated as likely even to exceed 300,000 tons in 1872.

Reports that immense discoveries of carbonate of iron have been made in Luxemburg and in the Grand Duchy, have very recently attracted much attention, but as yet no reliable information has been obtained concerning these deposits.

FRANCE.

The law just passed by the Assemblee Nationale regarding the merchant navy will have considerable influence on the steel manufacture of France, since it imposes an additional duty on all goods, except the produce of French colonies, imported in foreign bottoms; from European countries, including, of course, the Mediterranean shores, this amounts to 0.75 francs (7¼d.)

per 100 kilogrammes (220 lbs.); so that the iron ores from Corsica, Elba, Africa, Spain, etc., which usually arrive in foreign ships, will be subjected to a tax of some 6s. per metrical ton (2,206½ lbs.) a duty which is out of all proportion, considering that such ores only cost from 6s. to 8s. at the mine, and are annually imported into France at the rate of between 300,000 and 400,000 tons.

As regards the iron manufacture, things are looking very much better in all parts of France; the position of the ironworks in the Muerthe group is excellent, and their products deservedly in favor. All the establishments in the Muerthe Moselle have resumed work, and are in full operation. At Nancy, 18 blast furnaces, and at Longwy 9 are in work. Some new furnaces in the Haute Marne group have also been blown in, as well as some new coke furnaces pertaining to the Anzin Company. The works of the Marquis de Lambertye at Cons-la-grandville, in the Arrondissment de Briey, are again in operation, and the Orges and Châteauvillian furnaces are about to be put into blast. From St. Dizier the completion of two large furnaces, one at Brousseval, and the other at Marnaval, St. Dizier, are reported, and the journal "La Houille" announces the erection of six new blast furnaces in the Chavigny district.

Difficulties are still experienced from defective railway and river communication, many of the bridges broken down in the war not being as yet rebuilt, and the navigation of the Seine much interrupted by the works involved in their repair. Combinations have been formed to reduce as much as possible the inconvenience attendant on this state of things and the scanty means of transport: thus several masters in the Longwy district, MM. Giraud, Labbé, Helson, and D'Huart have arranged for a daily train of 250 tons from the central basin, which is divided *pro rata* amongst the co-operating firms; at present, however, everything tends to maintain the high prices of coal and coke.

The productions of cast iron in France, during the second half of 1871, is returned at a total of 486,090 tons, of which, 87,334 tons are foundry, and 398,756 tons forge pig; this shows a diminution of 230,000 tons, or about 33 per cent. less, when compared with the production of the second half of the year 1869, of which one half is probably due to the loss of territory now annexed to Germany. During the second half of 1871, the make of wrought iron is reported at 69,491 tons of rails, 48,484 tons of plates, and 256,540 tons of other descriptions of wrought iron.

The importation of cast and wrought iron and iron ores into France, during the years 1870 and 1871, is returned as follows:—

Importations.	1870.	1871.	Decrease.
	Tons.	Tons.	Tons.
Pig iron and castings	139,113	91,107	48,006
Wrought iron.....	75,116	27,578	47,538
Iron ores.	485,093	378,577	106,416

The falling off in the importation of iron ores is due principally to the smaller quantity of ore received from Germany. The details of the imported ores show Algeria to have sent 155,608 tons; Belgium, 92,228 tons; Spain, 91,427 tons; Italy, 31,649 tons; Germany, 6,000 tons; Switzerland, 19 tons; and other countries 1,646 tons.

In 1869, France produced 52,000 tons steel, or about twenty-nine times as much as in 1864, and in the first half of 1870 no less than 44,419 tons; so that it is estimated as soon as France recovers from the effects of the late war, that the country can turn out some 90,000 tons annually. In 1871, the Terre Noire Works sent steel rails to the United States for £30,000, which is the first occasion of any exportation of steel rails from France to that country; in the second half of last year 22,850 tons of steel rails were rolled in France, and 4,881 tons of steel in bars and other forms were also produced.

A new memoir by M. Gruner, professor of metallurgy at the School of Mines in Paris, has just appeared, and contains the results of his investigations on the action of carbonic oxide upon metallic iron and on the oxides of that metal, "Mémoire sur le dédoublement de l'oxyde de carbone sour l'action combinée du fer métallique et des oxydes de se métal par M. L. Gruner." A short notice of M. Gruner's results has already been given in the last quarter's report for 1871, but the study of this memoir is recommended as throwing considerable light upon previously but little understood, although very important, phenomena.

GERMANY.

About the middle of March, arrangements were completed for the amalgamation of

three of the largest ironworks in Rhenish Prussia, viz., Heinrichshuette, New Schottland, and Dortsmundshuette, under the name of Union Company, the object of which is to carry on coal and iron mines along with iron and steel works, with a capital of £1,650,000 in ordinary, and £650,000 in preference shares. The principal people interested in this Company are the banking firms of Rothschild of Frankfort, Oppenheim of Cologne, the Discount Company of Berlin, and the Provincial Discount Company of Hanover, in conjunction with several wealthy gentlemen of Rhenish Prussia. The works now belonging to the new Company are well located. Heinrichshuette has four blast furnaces of large dimensions, a Bessemer steel works, fifty-six puddling furnaces, and a forge with rolling mill, besides the Karl Friedrich coal mine, and exellent iron mines of Spathic carbonate, brown and red hematites and black band ores, situated in Westphalia, Siegen, and Nassau. New Schottland also possesses four blast furnaces, two at Hasslinghausen, and two at Horst, at which place there are also Bessemer steel works, two large forges and rolling mills at Horst and Aplerbeck, and two mines of black band iron ore, situated respectively at Hiddinghausen and Neustueter. The Dortmundshuette comprises a large forge and rolling mills, with over 100 puddling furnaces, at Dortmund; two blast furnaces at Gothfresen, and the extensive Gluckauf coal mine, near Dortmund. These works, which are situated in the centre of the Ruhr coal basin, having ample railway facilities in all directions, are considered capable of producing annually from their own mines and works about 100,000 tons of pig iron, along with 150,000 tons of rails and other wrought iron, and 20,000 tons of steel.

In Western Germany, special attention is now being devoted to the production of Bessemer pig and to spiegeleisen, for exportation to Bessemer steel works in other countries; in consequence of the increased demand, the prices both of spiegeleisen, and of the manganiferous ores from which it is made, have advanced still more, and most of the ironworks are doing a splendid business.

The Bessemer pig from the Georg-Marienhuette, near Osnabrueck, is in great request for making steel-rails and puddled steel, both in the vicinity, and as well as in Saxony in Austria. Even in 1870, during the war, this establishment paid a dividend of 8 per cent., and it is anticipated that for 1871 they will declare one of 15 per cent. With four blast furnaces in constant operation, the works turn out about 65,000 tons of Bessemer pig, using for this purpose about 160,000 tons of ore along with 150,000 tons of coal. The ores are somewhat calcareous, consisting of hard crystalline manganiferous cabonates of iron and soft brown hematites, derived from the Hueggel hills in the Teutoburger Wald, about seven miles south-west of Osnabrueck, where they occur in a deposit from 18 to 37 ft. thick, dipping 26 deg. to the north-east, which is known to extend some 2½ miles, and is worked in open terraces at the mines of Hermine, Brockmann, and Bothenberg, but underground in the Hedwig mine; in 1870, these mines yielded 180,963 tons of iron ore.

The larger portion of the coal consumed in these works comes from Westphalia, but in 1870, 45,025 tons were obtained from the Oesede and Bargloh collieries, to the south-east, which are connected with the works by a railway. The works were commenced in 1858 with one blast furnace, but did not prove a success for the first few years; they now, however, have six blast furnaces, and employ 1,500 men. The blast furnaces are 58 ft. high, with from 13 to 16 ft. diameter, and a capacity of from 6,131 to 8,286 cubic ft., and are worked on Luhrmann's system of closed breasts, with constant efflux of slag through the slag openings. The blast is supplied by five blowing engines, with horizontal cylinders, the steam-cylinders being 51 in. and the blowing cylinders 108 in. in diameter, whilst the stroke is 7 ft. in both. The piston rods are hollow, 14 in. diameter, and 1¾ in. thick. The pressure of the blast is from 4½ to 4¾ lbs. on the square inch, and the engines work with from 45 to 46 lbs. steam pressure, ⅝ expansion, and 21 strokes per minute. The hot air stoves are on the free suspended pipe system, each having 1,400 sq. ft. of heating surface, and are capable of raising the blast to a temperature of 850 deg. to 930 deg. Fahrenheit. Three such stoves, heated by separate fires, are attached to each blast furnace.

The principal railways of the Rhenish provinces and their connections have concluded an agreement by which all raw materials, like coals, ore, limestone, etc., are to be carried at the rate of one pfenning per

100 kilogrammes per mile, or about five-eighths of a penny per ton per mile, an arrangement calculated to be of much importance to the iron trade of these districts. The general state of the iron trade on the Rhine has been exceedingly brisk, and has now quite recovered from the effects of the war.

In Silesia, a company bearing the name of the "Vereinigte Laura und Koenigshuette," with a capital of 6,000,000 Prussian dollars, was established in June last, for the purchase and working of the iron-works and collieries known under these names, both of which were the property of Count Henckel of Donnersmarck, who, however, had only purchased the Koenigshuette works from the Prussian Government the year before, when they were put up and knocked down to him by public auction.

During the first half-year of this new Company's existence, which is just terminated, the production of pig iron from their blast furnaces amounted to 43,106 metrical tons, nearly the whole of which had been utilized by the puddling furnaces and rolling mills of the Company, which, during the same period, turned out 31,987 tons of wrought iron, chiefly in the form of rails and plate.

The details of the iron and steel industries of Prussia, during the year 1870, were entered into in our last quarterly report, and in connection with this the following figures, obtained from another source, are given for comparison :—

Iron ore extracted in 1870	.....	2,676,400 tons.
Pig iron made	"	1,123,422 "
Castings made	"	236,856 "
Wrought iron made	"	627,900 "
Plate and wire made	"	128,193 "
Steel of all kinds made	"	157,901 "

According to the mining and metallurgical statistics of the kingdom of Saxony, as given in the Jahrbuch fur den Berg und Huettenmann auf das Jahr 1872, the total amount of iron ore raised to the surface during the year 1870, which is the last official return, did not amount to more than 16,061 metrical tons, valued at under £12,000.

Much attention has been given of late in Germany to the question of machine puddling, and the probable influence which its general introduction may have on the iron trade of the country. A long article on the subject, by M. Cappe, in the "Gluckauf" journal, concludes by stating: "Although the results already obtained do not appear so great as to lead to a complete revolution in the system of puddling, that nevertheless, if, as appears probable, it does economize in reheating the balls, and reducing the consumption of coal and manual labor, the Danks furnace may have a great future wherever the ore is cheap, the pig-iron and labor dear, or where good workmen are scarce."

The great cast steel works of Friedrich Krupp, at Essen, in Rhenish Prussia, employed during the year 1871, 8,810 workmen, and turned out 75,000 metrical tons of cast steel, in the form of axles, tyres, rails, shafts, rolls, boiler plates, springs, artillery, projectiles, etc. The plants consisted of 528 annealing and cementing furnaces; 260 heating, re-heating, and puddling furnaces; 245 coke furnaces; 130 miscellaneous furnaces; 169 forges; 174 steam boilers; 343 lathes; 73 shaping machines; 130 planing machines; 172 punching machines; 303 other machines, of all kinds; and 58 steam hammers, varying in weight from 2 cwt. up to 30 tons, the three larger being of about 10, 20, and 30 tons respectively. The steam engines on this establishment were 265 in number, varying in force from 2 up to 1,000 horse-power, and representing in the aggregate no less than 8,559 horse-power.

ITALY.

The mines of iron ore at San Leone, near Cagliari, in the Island of Sardinia, which are now being worked by the French Company MM. Petin et Gaudet, are located in the Silurian Slates, and are lodes running nearly magnetic north and south, with an underlay to the west; they contain an abundance of garnets with a little quartz, and the ore, which is a native oxide of iron, has the following composition :—

Sesquioxide of iron	62.00
Protoxide of iron	24.00
Oxide of manganese	0.80
Sulphur	0.20
Loss on ignition	13.00
	100.00
Percentage of metallic iron..... ..	62.06

The exportation of iron ores from Italy to other countries, especially France, which last year imported 31,649 tons, is gradually increasing, the ores themselves being in general both rich and of extremely good quality.

SPAIN.

All the information received from this country since our last reports, relates exclusively to the activity which English enterprise and capital is now displaying in developing the extensive and valuable deposits of rich iron ores, known to exist in many parts of the Peninsula, in order to supply the British ironmaster with ores of high quality, suitable for the manufacture of Bessemer steel; amongst these we find a new company, entitled "The Malaga Magnetic Iron Ore Company, Limited," which has been brought out recently, for the purpose of working and shipping to England the rich and extensive deposits of iron ore in the valley of La Palmitera, about 16 miles from the Coast of the Mediterranean. The two deposits, called respectively "La Colosal" and "El Auxiliar," appear to be but parts of one great lode of native magnetic oxide of iron, the quality of which may be judged from the following analysis, by Dr. Wallace, of Glasgow:

	La Colosal.		El Auxiliar.
Peroxide of iron	68.04	..	70.40
Protoxide of iron	21.37	..	21.96
Oxide of manganese	1.40	..	traces
Lime	20	..	traces.
Magnesia	1.18	..	3.36
Alumina	3.42	..	1.50
Silica	2.60	..	0.30
Sulphur	0.04	..	0.04
Phosphorus	0.01	..	—
Water, with traces of carbonic acid	1.74	..	2.44
	100.00	..	100.00
Percentage of metallic iron	64 25	..	66 36

There is no doubt about ore of this character being well adapted for the production of pig iron, suitable for conversion into Bessemer steel; but it is a mistake to imagine, as stated in Dr. Wallace's report, that such ore will be more readily smelted than the Whitehaven hematite, as it is well known to all who have had practical experience in the working of such ores in blast furnaces, that the native sesquioxides of iron are much easier of reduction than the magnetic oxides, which, unless submitted to a previous calcination, are as a rule very refractory. The importation of this ore into England would, no doubt, be welcomed by our ironmasters; yet it is to be feared that the freight from the Mediterranean to this country will, in practice, prove much higher than anticipated in the prospectus of the Company, if the exportation of this iron ore is to be conducted upon anything like a large scale.

Several other mines of magnetic oxide of iron in the South of Spain and in Portugal are understood to be in the market for purchase, but as yet have not been taken up.

The exportation of iron ore from the Bilbao district of England is now carried on as actively as the present extremely defective arrangement for transporting the ore to shipping places on the river and for loading it into the vessels will admit of. A considerable quantity of ore is sent down the river in barges, from the brown hematite mines, located above the city of Bilbao, and loaded into vessels at Olaveaga, some four miles below the town, to which place ships drawing up to 18 ft. of water can ascend; the main supply, however, comes from the great mines of hydrous red hematite in the cretaceous formation at Somorostro, from which at present there is only a single line of rails (another is, we understand, projected, if not already commenced) to the shipping port of San Nicolas. This does not, owing to the defective means of loading from want of sufficient quay room, and the customs regulations which prohibit night work, admit of more than 1,300 tons per day being loaded, so that there are at present, no hopes of exporting more than between 400,000 and 500,000 tons per annum; yet it is notorious that about 600,000 are already contracted for for delivery this year, and the port is already crowded with vessels waiting their turn, and incurring enormous sums for demurrage, which in greater part will fall on the charterers in England, so that the cost of the Bilbao ore when delivered in Welsh or English ports is out of all proportion high, owing to these impediments in the way of getting the ore from the mines placed on board the ships. The inauguration of the mineral railway from the mines of the Bilbao Iron Ore Company, at Galdames, to the mouth of the river of Bilbao at Sestao, took place on the 30th January, and the works are being vigorously prosecuted.

Another English company, called the Spanish Hematite Company, has commenced working of the San Miguel Iron Mines, near Irun, in the province of Guipuscoa, with the object of exporting hydrous hematites and spathic carbonates of iron to England and France. The mines of this district, or of the Bidassoa, as they are usually termed in France, exported to that country, before the stagnation in the iron trade of France caused by the war with

Germany, about 1,500 tons of iron ore per month, and are again attracting attention. Their development hitherto has been retarded mainly from the want of railway communication from the mines to the shipping port.

The Santander Mining Company has also been brought out, with the object of acquiring and working certain iron and other mines in the north of Spain.

SWEDEN.

The present high prices for iron, and especially so for the higher qualities of charcoal iron, have, as might be expected, done good service to the Swedish ironmasters, who have made every effort to increase this production to its utmost; this being, however, limited by the annual supply of charcoal which can be procured from the forests, has not allowed of being much augmented either by any considerable extension of the present or by the erection of new works for the production of charcoal iron; attention has, therefore, been directed to the utilization of the superabundance of rich iron ores in the central iron district of Sweden by exporting them to England and Belgium, and also on a smaller scale by smelting the iron ores on the spot with coke from England, brought over as return freight by the ships which will carry iron ores to that country.

Arrangements are, it is understood, now being made both on English and Swedish account, for working the iron mines located along the line of the new Swedish Central Railway, and for exporting the ores as soon as that railway is opened for traffic, which is expected to be some time this summer. The quality of these ores is unexceptionable, and in richness they vary from 50 to 60 per cent. metallic iron. Although less prices have been announced, it is not probable that these ores can be delivered on the east cost of England, owing to the long overland carriage, under, at the lowest, 25 shillings per ton.

An English company, entitled "The Swedish Central Iron and Steel Company, Limited," has been established, and commenced operations with the twofold object of working both charcoal and coke furnaces in connection with Bessemer steel works and rolling mills. At Bjorneborg, in the western part of this district, their operations are confined to the manufacture of charcoal iron for the production of Bessemer steel plates and tyres of the finest quality; whilst at Frotuna, two large blast furnaces are in course of erection for smeltiug iron ores brought from the iron mines situated along the Swedish Central Railway, from which an ample supply can be had at extremely low prices. The fuel to be employed is coke from England, and the product, after conversion direct from the furnaces into Bessemer steel, is to be rolled into rails for consumption in Sweden, and exportation to Russia and Germany. The richness, purity, and cheapness of the iron ores, the magnificent water power, and ample supply of cheap labor at command, and the proximity of the markets for the manufactured products, are advantages which are expected to more than counterbalance the extra expense of the combustible, and are considered to insure the success of the undertaking.

UNITED STATES.

The annual meeting of the American Iron and Steel Association was held at New York, on the 11th January last, under the presidency of Mr. Samuel J. Reeves. The report of the Secretary, Mr. Henry McAllister, Jun., was read, and discussions took place on subjects connected with the iron and steel trades, the entire tenor of which was to advocate and defend the protective duties, and to attempt to prove them as advantageous to the country in general, as they are, no doubt, to the ironmasters of the United States in particular.

The National Association of Bar Iron Manufacturers assembled at the Continental Hotel, Philadelphia, on the 10th and 11th of January last, under the presidency of Mr. James J. Bennett. The objects of this Association are stated to be "for the purpose of obtaining full statistics of the iron trade throughout the world, and effecting frequent interchange of ideas, improving the manufacture of iron in the United States, and securing harmonious action in all matters pertaining to the iron interests." The report of the Secretary was a very lengthly document, and as it contains a retrospect of the state of the iron industry of the United States in 1871, probably more correct than any other data at our command at present, a rather full abstract of the portion relating to the production of iron in the States is here appended.

The estimated production of pig iron in 1871 is given as follows:—

Anthracite pig—		
Lehigh region	275,00	
Schuylkill	142 000	
Upper Susquehanna	118,000	
Lower do.	118,000	
East group (E. and N. of Pa.)	210,000	
		863,000
Raw coal and pig iron		600,000
Charcoal pig—		
New England	35,000	
New York, New Jersey, Pennsylvania, and Madison	137,000	
Western States	200,000	
Southern do.	15,000	
		387,000
Total in tons of 2,000 lbs. each		1,850,000

The details of the statistics are as follows:—

Pensylvania, 38 blast furnaces produced 378,000; three others, each capable of turning out 9,000 tons, are in course of construction—of the ores employed, 70 per cent. was hematite from Lehigh, Berks, and Northampton counties, the remainder from the mines of New Jersey, South Mountain, Pennsylvania, and magnetic ores. The coal is from the Lehigh anthracite mines, and from the Wyoming and Schuylkill district, while the limestone is from the immediate neighborhood of the furnaces.

The Schuylkill region is equal to a make of 160,300 tons, with all the furnaces in blast; the Leesport and the Hooven furnaces at Norristown, representing 21,000 tons, were, however, standing idle.

Of the regions of Pensylvania, 7 furnaces, representing 70,000 tons, exist in Pittsburgh and immediate vicinity, while six more are in course of erection, four of them 75 ft. high, two being 18, and two 20 ft. diameter at the boshes; these are estimated to add, in 1872, 90,000 tons more, and thus make a total of 160,000 tons pig iron in Pittsburgh in 1872.

In the Shenango Valley, 23 furnaces produced 192,000 tons, and in the course of construction are three blast furnaces at Wampum, equal to an estimated annual make of 47,000 tons; one at Newcastle, 23,000 tons; one at Sharon, and one at Sharpsville, each equal to 12,000 tons. The remaining production comes from the districts of Harrisburg and Juniata, Lower Susquehanna, Danville, and Johnston.

The Mahoning Valley, with 21 blast furnaces, yielding 203,000 tons, in the prominent iron-producing region of Ohio, using its own block coal along with ores from Lake Superior.

No statistics had been received from the blast furnaces at Ironton and its vicinity, but at Cleveland, two blast furnaces turned out 17,000 tons.

The Lake Superior region of Michigan produced 958,520 tons iron ores in 1870, and nearly 1,250,000 tons in 1871, which employed above 200 vessels in its transport. Within the district are fifteen furnaces, which yielded 50,000 tons pig iron, whilst outside it, in Michigan, are two furnaces at Wyandotte, of capacity of 8,000 tons, along with one or two others not noted.

The increasing iron production in the North-West is remarkable, especially in Wisconsin, where there are now ten furnaces in blast, with a total product of 67,-900 tons. Of these, two furnaces at Milwaukee make 30,000 tons, with bituminous and anthracite coal and coke; all the rest are charcoal furnaces; three of these using Wisconsin ore, turned out respectively 2,500, 2,700, and 3,300 tons, but of the five others, four made 6,000 tons each, and the remaining one, 5,400 tons, being much larger; the average consumption of charcoal in a 6,000 tons furnace being 700,000 bushels, equivalent to 21,000 cords of wood, which, on a average, is reckoned at thirty cords to the acre of land. The average price was 8 cents per bushel, and 100 bushels were required to the ton of pig iron.

Missouri has fifteen blast furnaces, and produced 129,500 tons, of which 44,500 was charcoal pig iron made in eight furnaces, three of which were driven by cold, and five by hot blast; the remaining 85,000 tons were made with coal in seven furnaces.

At Chicago, two furnaces, with a capacity of 35,000 tons, consume coal from Erie and Pittsburgh, in Pennsylvania; and at Joliet, two furnaces produce 25,000 tons.

Indiana has seven blast furnaces consuming the block coal of the locality, and smelting Lake Superior and Iron Mountain ores; the pig produced is now being extensively employed for conversion into Bessemer steel.

No complete report has been received from Georgia, Alabama, Kentucky, Tennessee, Virginia, or from the Northern and Eastern furnaces.

The total consumption of iron in the United States, for 1870, is given at about 2,000,000 tons, of which one half went into railroads; this quantity is equivalent to 115 lbs. per head in the population; in 1867,

the consumption was, in England, 189, and in France, 69½ lbs per head.

Before closing the proceedings, which adjourned to meet in Pittsburgh in May, the Association adopted the following resolutions, which afford the most convincing proofs of how much the iron trade of the United States is wedded to and dependent on the protective duties by which external competition is, to a great extent, annihilated.

"We, the bar iron manufacturers of the United States, in convention assembled at Philadelphia, representing the kindred interests of over a million workmen, the value of whose products, in 1871, amounted to 900,000,000 dollars, do resolve :—

"*First.*—That in the adjustment of the national revenue, the wages of labor and the interest of capital should be taken into account, and no changes made to their injury.

"*Second.*—That the enormous increase of our iron manufactures within the last decade, and the collateral benefit to the industry of the whole country, can be traced to the protection given to the iron interests during that period.

"*Third.*—That the present prosperity of labor in the United States, enabling the working man to occupy a higher position in social life, with privileges and comforts unknown to the workmen of any other country, is attributable to the liberal wages paid for labor under a protective policy.

"*Fourth.*—That these wages are dependent upon the price of the manufactured article, and a reduction in the tariff means a reduction in the wages paid to American labor.

"*Fifth.*—That the present duties upon iron are not giving to labor and capital more than a fair return for the work performed, and the risks involved, and that any reduction in the tariff would eventually close our mills and furnaces, leave without means of support our workmen, prove disastrous to the farmers and shopkeepers, and cripple all other industrial pursuits.

"*Sixth.*—That further, as American citizens, we protest against the adoption of any policy which shall retard the development of our country, and place us in a condition of dependence upon foreign nations for our manufactures."

Notwithstanding the detailed account of the production of pig iron in the United States, given in the report of the Secretary of the Bar Iron Manufacturers' Association, this body does not appear to have paid anything like the same attention to the statistics of their own particular branch, the wrought-iron trade, so that we can only give a summary of its condition during the last eight years, in the following tabular statement, given on the authority of the Secretary of the American Iron and Steel Association :—

Year.	Rails.	Other than rails.	Total annual make.
1864	335,369	536,958	872,327
1865	356,292	500,048	356,340
1866	430,778	595,311	1,026,089
1867	462,108	579,838	1,041,946
1868	506,714	598,286	1,105,000
1869	593,420	642,420	1,236,006
1870	620,000	710,000	1,330,000
1871	750,000	713,000	1,463,000

The last year's estimate is only an approximative one, as the returns are not yet made up. The number of rolling mills of different descriptions in the United States in 1871 is stated at nearly 300; and, as considerable extensions are being made in all directions, a larger increase in the make for this year is anticipated.

Mr. J. W. Forster, in comparing the iron ores of the Lake Superior district and of Missouri with those of Sweden, gives the former the preference, owing to their, according to him, containing less sulphur, and not requiring calcination before smelting in the blast furnace. He does not, however, seem to be aware that Swedish ores exported to and smelted in Belgium and England are not calcined, but charged into the furnace in the raw state, and that the reason why in Sweden these ores are invariably calcined is not on account of the sulphur they contain (a large number of them being practically free from sulphur, as well as phosphorus), or because a preliminary calcination is imperative, but because long experience has proved that it pays to calcine them, as it renders them more easily reducible, and it is found much more economical to effect this part of the smelting progress outside the blast furnace by the waste gases from it, than inside the furnace, at the expense of the more costly solid combustible.

Amongst the ores of the Lake Superior district, besides the magnetic and specular oxides of iron, are large deposits of hydrated oxides or brown hematites, some of them manganiferous. These ores are principally consumed in the blast furnaces of the Mahoning Valley, in Ohio; the Chenango Valley, in Pennsylvania; at Pittsburgh,

Buffalo, Cleveland, Massillon, Dover, Toledo, Detroit, and Brazil; the ironmasters of Northern Ohio and Western Pennsylvania having by experience found it more advantageous to employ the pure rich ores brought from a distance, than the lean and less pure ores from the immediate neighborhood of their own furnaces. At Buffalo, these ores are smelted with anthracite from Pittston; at Pittsburgh, with coke made from the coal of the vicinity, or from Connellsville, some sixty miles distant; whilst at Cleveland, coke from the Pittsburgh district is employed. In the Mahoning and Chenango Valleys, the coal is used in the raw state, as also at Brazil; whilst at Toledo and Detroit, charcoal is largely consumed.

The make of pig iron in the Lake Superior district, in 1871, is given at 51,225 tons, as compared with 49,298 tons in 1870; 39,003 tons in 1869, and 38,246, in 1868; whilst the value of the iron ores and pig iron taken together, is stated at 6,115,895 dollars in 1871, as compared with 2,405,960 in 1866; 419,501 in 1861, and in 1856 only 28,000 dollars; from which figures, an idea may be formed of the rate at which the iron industry in this district has progressed during the last quarter of a century.

In Pennsylvania, the extension of operations are equally as remarkable in the finished iron trade as in the production of pig iron. All the mills are in great activity, especially around Pittsburgh, where the rolling mills exclusively engaged in making bar and hoop iron (not including rails, plate, sheet, or nails) occupy 609 puddling furnaces, whilst the Chenango Valley employ 135 more. A new company, entitled the De Graaf Iron Works, have purchased the Laurence Iron Works, at Newcastle, which contain 17 puddling and 4 heating furnaces, as well as the extensive rail mill belonging to Messrs. Dithridge & Co., of Pittsburgh. At the Onondago Works, Newcastle, 8 puddling furnaces and a nail works are being erected; a rolling mill, with 3 trains of rolls, is in course of construction at Milton, by the Milton Iron Co., and Messrs. Lyon, Short, & Co., have put up a double puddling furnace. It may also be mentioned that the rolling mill belonging to Messrs. Harbaugh, Mathias, & Owens, at Pittsburgh, with 10 heating furnaces, turned out 36,336 tons of rails in the course of 1871, and no less than 1,115 tons in one week in the month of December last.

The St. Charles Iron Company has recently been established in Pennsylvania, with a capital of 1,000,000 dollars, in shares of 7 dollars each, for the purpose of erecting ten blast furnaces at Reading, each furnace being calculated to turn out 11,000 tons per anum. The cost of the ore delivered at the furnaces is estimated at 3 dollars per ton, and the cost price of the pig on the works at 20 dollars per ton, so that, according to American prices, there should be a large margin for profit.

In Ohio, the manufacture is making rapid strides; Cleveland now has fourteen rolling mills, with 200 puddling furnaces, which are capable of turning out 400 tons of finished iron per day. At Columbus, large works have been erected; a new company has started the Bellaire Rail Mill, with fourteen puddling furnaces and three heating furnaces, and propose adding two more puddling furnaces and one blast furnace.

The Stebensville Furnace and Iron Company has lately been incorporated, with a capital of 300,000 dollars, in shares of 100 dollars each; and the Union Iron Company are building a blast furnace at Newbergen.

A British company, called the Glasgow Port Washington Iron and Coal Company, has recently been formed for acquiring some 860 acres of freehold land, working the deposits of black band ironstone and coal under the same, the former of which are estimated to contain 2,595,820 tons of iron ore, along with beds of fire clay and workable coal, five seams of which are stated to be from 2½ to 8 ft. in thickness. This property, known as the Port Washington estate, is situated in the county of Tuscarawas, in Ohio, and is in the immediate vicinity of the Ohio State Canal, and the Pittsburgh, Cincinnati, and St. Louis Railway. Operations have already been commenced, and blast furnaces are being erected, it being estimated that the ironstone on these properties will supply two blast furnaces for forty years.

At Ironton, the Ohio and Pine Grove furnaces have been blown out, and will not resume work before May. In the Mahoning Valley there are now six mills, containing 149 puddling furnaces.

In Illinois, the rolling mills at Chicago fortunately escaped the fire, and are in active operation.

In Missouri, the consumption of Iron Mountain ore has increased so largely that

the extraction for this year is estimated by Mr. Chouteaux at 350,000 tons; this State contains three rolling mills, all situated at or near St. Louis.

The entire production of rails in the United States during 1871 is estimated at about 750,000 tons. No estimate of the quantity of plates has been received, although it is stated to be very large.

The attempt to manufacture steel from the iron sand of the beach having proved a complate failure, the machinery and fixtures of the steel works opposite West Hampton have been sold.

BRIEF NOTES ON RECENT CHANGES IN BRITISH ARTILLERY MATÉRIEL.

By CAPT. S. P. OLIVER, F.R.G.S.

From "The Quarterly Journal of Science."

In looking through the Extracts of the Quarterly Report of Proceedings of the Department of the Director-General of Ordnance, it will be observed that the labors of the various committees have not been light or unsuccessful. The results of various experiments and proposals are given by at least a dozen of these said committees, of whom the principal are the following, viz., committees on mitrailleurs, on torpedoes, on range-finders, on gunpowder and other explosives, on ship's deck and turret targets, on mountain artillery equipment, on rifled shell guns for field service and heavy rifled howitzers and mortars for vertical fire, on Palliser's method of strengthening cast-iron guns with internal tubes, on Palliser's projectiles, on traversing arrangements, on wads for preventing erosion of bore, on Moncrieff carriages, on shells and percussion fuzes for field service, on improvements of bronze, on proportions of ammunition for ordnance and small arms to be maintained in fortresses at home and abroad, besides Noble's important electro-ballistic experiments, and Majendie's experiments relative to the distance of cartridge-filling sheds, etc.

From an inspection of the reports of the above, it would appear that the following results are noticeable as affecting future warfare and modern requirements:—

I. The immediate introduction into the service of the small Gatling gun of 3 cwt., with musket-proof shields, and to be drawn by two horses. This gun is found o be a most effective weapon in defending villages, field intrenchments, caponnières, for covering the approach to bridges or *têtes-du-pont*, for defending a breach, and for employment in advanced trenches and field-works where economy of space is important. For naval purposes these machine guns are well adapted for use in the tops of vessels of war, for boat operations, service up close rivers, etc.

II. Gunpowder Service P. (as the pebble-powder described in the last number of the "Quarterly Journal of Science" is officially designated) is to be introduced for battering charges of all rifled guns of 7 in. calibre and upwards, and for all service-charges of 40 lbs. and upwards, so soon as a sufficient quantity has been manufactured.

III. Additional experimental proof of the special value of compressed gun-cotton for demolition of stockades, bridges, etc., and for submarine mines. Capt. Noble also proposes to apply gun-cotton yarn as a fuze priming, it possessing the advantage of consuming almost instantaneously, thus not interfering with the burning of the fuze, whilst its sensitiveness makes ignition certain, even by the lowest charge.

IV. "Picric powder" is not unlikely to be used in future. It is an invention of the War Department chemist, Mr. Abel, who has been designing this explosive agent specially provided for charging shells. This mixture is neither so violent in its action as gun-cotton, nitroglycerine, or picrate of potash powder, but at the same time is a much more powerful explosive than gunpowder, and has other properties which appear to render it peculiarly adapted for employment in shells; it is readily and expeditiously prepared, can be pressed and granulated without difficulty, and at the same time is particularly remarkable for its *safety* as compared with all other explosive agents; it is, in fact, somewhat less sensitive to ignition by percussion than gunpowder. By recent experiments made it appears that picric powder, when used as a bursting

charge for Palliser shells, will sustain the action of battering charges of R.L.G. powder in guns up to and including the 9 in. of 12 tons; the safety of this substance is being further tested from 10 in. and 12 in. guns.

V. The last explosive compound to be noticed, as likely to take no small part in future warfare, is Kreb's patent "lithofracteur," which is in use in the Prussian service. From Mr. Abel's analysis it appears to be composed as follows:—

Nitroglycerine	42 parts
Nitrate of soda	25 "
Sulphur	4 "
Sand, silicious earth, sawdust, and coarsely-powdered coal	29 "
	100 "

The "lithofracteur" differs from the nitroglycerine preparation called "*dynamite*" chiefly in containing a proportion of gunpowder constituents, viz., saltpetre, carbon, and sulphur, mixed up with the other ingredients. From the samples analyzed it appears that this substance is crudely mixed, varies considerably in composition, and possesses no improvement over dynamite. On the 20th February, 1872, some exceedingly instructive trials of this compound were made—by Professor Engels, of M. Kreb's Cologne factory—at Mr. France's Breidden Quarry, on the banks of the Severn, near Shrewsbury, before the W. O. Committee, when it appears to have most favorably endured the various tests, both chemical (to ascertain the fuming and explosive points) and mechanical (to test its safety under heavy blows and concussion); for instance, 5 lbs. of lithofracteur was exposed to a fierce flame and consumed without explosion. Cartridges of it were subjected to heavy blows, such as the fall of round shot upon them, when the plastic substance, although squeezed out, neither inflamed nor exploded. Similarly, it was ignited by a Bickford fuze in confinement, and inflamed without explosion. Naked cartridges fixed to buffers of a railway truck, allowed to run on an incline into violent collision with a stationary one, also failed to explode. On the other hand, the same substance when fired with a Bickford fuze and detonator, in thin zinc tubes 4¼ in. in diameter, either against stockades, in mines, or under water, exploded with inconceivable violence, the explosion in each case being perfect. It was stated that M. Rietschoten has conceived the bold proposition of cutting through a sandbank of 1500 yards breadth, of Rotterdam, and so forming a deep channel through it by sinking tubing of that length charged with 10 tons of lithofracteur. For the defence of channels and entrances to our harbors nothing can be imagined more effective. The serious objection against it seems to be that, after keeping, the folds of thin paper of the cartridge become saturated with nitroglycerine, absorbed from the material within, so that, according to Mr. Abel, in the application of it the hands of the operators must become soiled with that poisonous substance. No doubt this will be obviated.

VI. For the better prevention of the erosion in the bores of rifled guns, various descriptions of wads have been proposed and experimented upon. The Royal Laboratory paper wads appear to be objectionable on account of pieces of them flying back in a state of ignition, which has, in the case of the Bolton's wads, been already supposed to account for a dangerous accident on board H.M.S. Minotaur, when a 14 lb. cartridge exploded in the hands of No. 3 of a detachment, by which two men were severely burnt and eleven others scorched and singed. A coating of Szerelemy's zopissa cement applied to Bolton's wads has also been found impracticable, as it is found not to prevent them catching fire and burning to a very dangerous extent. Col. Reilly proposes a hempen wad with tin or copper edges, similar to that used in the Prussian breech-loading rifled guns, which has been found to effectually check the rush of gas over the seat of the projectile. Capt. Noble has experimented on several natures of wads, consisting either of tin cups with short deep or split flanges, or of cowhide cups with similar flanges, or a combination of cowhide and tin cup; the conclusion arrived at being against the tin cups, in consequence of their tendency to fly about in front of the guns, whilst the cowhide cups with deep flanges appeared to answer best as a gas check. Although Major Bolton has succeeded in making wads of an uninflammable material, it is found that the scoring of the bore is not entirely prevented, and at present the question of wads in any known form remains in an unsatisfactory state.

VII. Although the traversing arrangements for naval guns are such that heavy muzzle-loading rifled guns, at close intervals, are worked with ease and rapidity between decks, still hitherto on shore batteries

—especially in casemates, where there is more room than on board ship—the old luff tackle traversing gear has been adhered to; and Sir Collingwood Dickson, the Inspector-General of Artillery, considers the present land traversing gear as utterly ineffective, the guns moving so slowly that it is impossible to obtain that rapidity of fire so absolutely necessary against ships moving under steam. Mr. Cunningham's ingenious training gear fitted outside the rear racer, has been found to interfere with the convenient service of the gun; but a new system of coupling two fore or two hind trucks together, and driving by friction, the power being communicated by means of bevelled and toothed gear, is now recommended for general adoption: this plan possesses the great advantage of having the gear wholly contained in the platform; the matter is, however, of so much importance that the various details must be well considered before patterns are sealed.

VIII. The facilitation of loading heavy guns is also a question of importance, especially in bringing up the heavy shell and placing it in the bore; consequently various alterations have been made to shot-bearers and barrows, slings, muzzle-derricks, etc. With the same view it has been decided to ease off the loading siding side of the grooves at the muzzle, to facilitate the entry of the projectile into the bore. This is done by cutting away the lands, and thus widening the grooves to the extent of 1 in., tapering down to the original width of the groove in a length of 2 in., measured parallel to the axis of the bore, the corners being well rounded off.

IX. Amongst other changes, necessitated by the introduction of pebble powder, have been the regraduation and assimilation of Land-service and Sea-service tangent sights; and advantage has been taken of this opportunity to secure, as fully as the various classes of projectiles will allow, the introduction of an uniform system of applying the information which is engraved on the sight bars; and as the slow motion elevating screw in tangent scales for land service is abolished in sights for guns of 64-pounder calibre and upwards, the land and sea service sights for guns of these natures will be interchangeable. Take the 7 in. M. L., for instance, the following information is to be found on the hexagonal bar of its centre hind sight:—On one side is given for double shell full range in yards, next common shell full fuze, common shell full yards, Palliser shot or shell and common shell battering yards, common shell battering fuze and double shell full fuze.

The above are, of course, only a very few of the numerous alterations which are gradually changing the character of our Artillery *materiel*; but these few desultory notes, in which our heavy ordnance manufacture and trials between targets and shot and shell are necessarily excluded, will serve to show that our factories are not at a stand-still. It is reported that Mr. Scott Russell has in hand a gun on an entirely new principle, with which he is going to astonish us.

STEAM ENGINE PERFORMANCES.

From "Engineering."

We have respeatedly had occasion to speak in this journal of the carelessness with which trials of steam engines are but too often conducted, and we have had to denounce the practice of founding assertions as to economical performances upon data which are but too often insufficient to afford a foundation for any accurate deductions whatever. The fact is that steam engine trials, conducted with that care and attention to minute details which are necessary to insure thoroughly trustworthy results, are but very rarely carried out, either on land or on shipboard, and it can scarcely be doubted that, as a consequence, the construction and general adoption of engines of economical types have been very greatly retarded, and there has ensued, for many years past, a waste of fuel which it is scarcely possible to estimate, but which must have been enormous. The present high price of coal has had some effect in leading steam-power users to search after sources of economy; but still it is comparatively rare to find even amongst the owners of large mills and factories, men who prosecute this search in anything like a systematic manner. But too frequently the steam user, who finds his coal bills heavier than he thinks they should be, lends his ear to

enterprising patentees, who recommend to him some fire-bars of eccentric form, a new fire-door, some wonderful expansion gear, or some other detail, which, it is declared, will, if adopted, secure an economy of almost any desired number of per cent. In some cases, where an alteration is made under these circumstances, an improvement is the result, because, simply by chance, the alteration is one that was needed; but in a great majority of instances, things remain the same, or perhaps become worse than they were before, and, after a few experiences of this kind, the owner, disgusted at innovations, decides to disregard all further suggestions as to improvements, and continues in his old and wasteful course rather than risk further failures.

Now we submit that this is not as it should be. Instead of proceeding in the hap-hazard way we have indicated, the user of steam power should, if he has reason to think that he is not getting economical results, call in the assistance of a competent engineer, and have the performance of his engine and boiler thoroughly and carefully tested. When that test has been made, and the performances of the engine and boiler ascertained independently, then, and not until then, should the idea of alterations be entertained, and their extent determined upon. It is, in fact, impossible to decide, until the actual performance of an engine or boiler is ascertained, how much it is advisable to spend upon alterations, so as to secure a result which shall be really economical; and we may remark here, that when the facts are known it will in many instances be found cheaper to replace the old engine by a new one of a more economical type, rather than to attempt to make improvements which will never be thoroughly satisfactory.

We know that there are many mill and factory owners who have a great horror of anything approaching an experiment. They regard engine and boiler trials merely as excuses for upsetting their usual working arrangements and disorganizing matters generally, without producing any commensurate result. This, however, is a great mistake. If conducted by competent engineers who know what such trials ought to be, and how they ought to be proceeded with, an engine and boiler trial may be carried out without in any way materially affecting the ordinary working of a mill or factory. It is, in fact, particularly desirable that an engine and boiler, when tested, should be working as nearly as possible under ordinary conditions, or otherwise false data may be obtained which will interfere with the deduction of correct results.

Of course, the carrying out of a proper trial of a mill engine with its boilers, cannot be done for nothing; but it certainly need not be a costly affair, and it is one which, in the vast majority of instances, will be promptly repaid by the sources of saving which it will point out to the steam user. We cannot, however, too thoroughly impress upon our readers that a steam engine trial, to be of real service, must be complete, and must be carried out by competent hands. It is of no use to take indicator diagrams from an engine at long intervals, to count the number of revolutions occasionally, to keep some kind of crude account of the amount of fuel consumed, and then from these "data" to deduce the consumption of coal per indicated horse power per hour. So-called trials are, we know, but too often conducted in the fashion to which we have alluded; but such trials are really worse than useless, as they not merely give results which are worthless in themselves, but by distributing untrustworthy facts broadcast, too often cause really genuine performances to be regarded at less than their proper value.

To be of real service, a trial must be so conducted as to distinguish clearly between the performance of the boiler and that of the engine. In testing the former it is no use proceeding on the plan of starting with a fire on the grate and ending with the fire in what is judged to be the same condition as at starting. It is quite impossible to judge of the quantity of fire in a grate with sufficient accuracy, and the only proper way of proceeding is to start with steam up and the grates completely cleared, and to end the trial under the same conditions, the fuel removed from the grates at the end of the run being of course weighed and duly credited in calculating the performance. The water evaporated also should be very carefully measured—or, what is still better, weighed—and its temperature should be recorded at frequent intervals, as should also the pressure of steam in the boiler.

In the case of the engine, indicator diagrams should be taken at regular intervals, these intervals being made more brief in proportion as the work may be irregular. If the work to be done is tolerably constant

it will be sufficient to take sets of diagrams from both ends of the cylinder or cylinders every quarter of an hour, but if there be great variation of power, the diagrams should be taken as frequently as possible, or what is still better, one of Ashton and Storey's continuous indicators should be used. We may state here that under no circumstances should diagrams obtained from one end of a cylinder be taken as representing the action of the steam at both ends, unless the fact of the uniformity of the diagrams has been proved by actual experiments. We have known many errors—and some serious ones—arise from a neglect of this precept.

Besides taking indicator diagrams, frequent observations should be made of the steam pressure in the engine room, the ratio of expansion (supposing that to be variable), and the drainage of condensed steam from the steam jacket, etc., while, almost above all, we attach particular importance to a careful record of the quantity of condensing water used, and of the temperature at which it escapes. We have on several occasions directed attention to the method of testing engines by observation of the quantity and temperature of the condensing water employed by Mr. B. W. Farey and Mr. Bryan Donkin, Junior, while we have also described the arrangement devised by them for keeping a record of the temperature and amount of water discharged from the hot well, and we may repeat here that we know of no other system of testing which is so trustworthy, or so well adapted for general application. The practice of measuring the quantity and temperature of the condensing water has also the advantage of forming an excellent check upon the observations in the boiler house, and from it, it can be in a great measure ascertained, whether or not the feed-water used has been fairly evaporated, or whether priming has taken place.

It is, as we have said, to the direct interest of mill and factory owners, that the performances of the engines and boilers employed by them should be thoroughly tested; but it is nevertheless true that there is considerable difficulty in getting this fact properly appreciated. This state of affairs is, we believe, to no inconsiderable extent, due to the want of a correct appreciation of the wastefulness of many classes of engines in general use, and probably nothing but a complete *exposé* of the faults of such engines will be of service in bringing about a better state of things. In the case of steamships, the facilities which exist for instituting a comparison between the fuel consumption of one vessel and that of another of about the same tonnage, engaged on similar service, have enabled comparisons to be instituted between different classes of engines, which, although necessarily only broadly approximate in their character, have nevertheless proved of good service. In the case of factory engines, however, no such means for ready comparison exists, and as the owners of inefficient steam engines seldom make thorough trials of them, and still more seldom publish the results of those trials to the world, the evil goes on, and promises to go on, for very many years to come.

Almost the only remedy for such a state of things, and certainly the only means we can think of for bringing the wastefulness of many types of engines prominently before the eyes of steam users, is the carrying out of a comprehensive series of public trials of steam engines. Already the competitive trials, conducted under the auspices of the Royal Agricultural Society, have done great service by showing the users of portable and small fixed engines, to how great an extent the performance of such engines is dependent upon proper design and construction, and how great is the economy which a really good engine is capable of effecting. What is now wanted is an extension of such trials as the Royal Agricultural Society have carried out, to larger engines and boilers of the types ordinarily employed in our mills and factories, and a publication of the results in a form which will render them generally appreciated by steam users.

But it will be argued that such experiments as we propose are practically impossible, on account of the great expense that would attend them, and we admit that under ordinary circumstances this would be an important difficulty. Next year, however, there will be an opportunity, such as has never before occurred, of carrying out such trials as those we advocate, and we most earnestly hope that it will not be allowed to slip by. At the Vienna Exhibition, with its vast machinery hall, and its annexes, there will be brought together such a collection of stationary engines and boilers as the world has never yet seen, and, more than this, there will exist every convenience for subjecting these engines to a thorough system

of trial. Under such circumstances it would be a subject for sincere regret if so rare an opportunity were allowed to pass away without being turned to account in the manner we have indicated. As yet no official intimation has been published that engine trials will be carried out at Vienna; but so much skill and energy is being displayed in organizing the various departments of the Exhibition, and in giving to the whole a thoroughly practical character, that we can scarcely suppose that such a grand opportunity as that we have pointed out should be neglected. Let such a series of international engine trials be carried out, and both steam engine builders and steam power users will have reason to remember gratefully the Vienna Exhibition of 1873.

LIGHTNING AND LIGHTNING CONDUCTORS.*

From "The Mechanics Magazine."

The number and intensity of the thunderstorms which have raged over this country during the past season, as well as the accidents which have accompanied them, have been so far above the average that they have attracted unusual attention to lightning and the means at our disposal to protect ourselves, our buildings, and our apparatus, from the destructive effects of electrical discharge. This, therefore, forms a most interesting subject for discussion before this Society. Recently the partial destruction of that magnificent building, the Escurial, one of the chief glories of Spain, and called the eighth wonder of the world, has added considerably to the interest felt in the subject.†

In this country, not only have trees been shattered, cattle destroyed, public buildings struck, and private houses injured, but human beings have been killed in such numbers, that if tabulated, they would probably cast into the shade the massacre committed by even our railway trains. The average number of deaths due to lightning in England, previous to this year, was 18; in France it was 95.

Mr. Symons, the well-known meteorologist, who has for many years devoted much attention to this subject, mentions that in two storms in June last nearly two hundred separate accidents came under his own knowledge, including the death of ten persons and injury to thirty-three others; upwards of sixty houses were struck, ten or fifteen of which were burned down. Twenty-three horses and cattle and ninety-nine sheep were killed. This is the imperfect record of only two storms. What must it be for the whole year?

But it is the damage done to our telegraphic system that more immediately interests this Society. I am able to give fairly complete returns of the injury inflicted on the apparatus and plant of the Postal Telegraph Department, and I am in hopes that the discussion which this paper is intended to inaugurate will elicit much important information of the damage done to our extensive Railway Telegraph System. The returns have been tabulated, and will accompany this paper as an appendix.

From January 1st to July 31st, 1872, of 9,475 instruments of different form in use in the department, 897 or 9.46 per cent. were injured. The different classes and number of apparatus used, and the amount of injury received by each, were as follows:

Instrument.	Number in use.	Number damaged.	Per cent.
Automatic	108	Nil.	
Hughes'	23	"	
Morse (Galvanometer)	1943	37	3.24
Morse (Recorder)		7	
Morse (Relays)		19	
Single needle	3536	364	10.29
Double needle	77	2	2 6
Alphabetical	3303	374	11 32
Bells' (Bright's)	485	22	4.55
Protectors	..	72	
Total	9475	897	9.46

The actual er direct estimated cost of these injuries is £905, that is, £905 is the direct claim of the Postal Telegraph Department against *Jupiter tonans;* but it by no means represents the indirect claims of the department against that potentate.

* From a paper read before the Society of Telegraph Engineers by W. H. Preece, Esq.

† The Escurial, since its comp'etion, in 1584, has been on fire no less than seven times, viz., in 1587, 1590, 1671, 1744, 1766, 1826, and 1872. The causes of two of these are unknown; but at least four of the fires arose from the lightning, yet there never has been one lightning-rod introduced into the Palace.

Thus it is impossible to estimate the loss of time on the part of the staff engaged in maintenance duties in visiting and revisiting stations damaged by lightning, or the effect of the delay in repairing the circuit upon the revenue, and the consequent detriment to the business. The total cost must be very large. If the damage inflicted upon our railway telegraphs and the delay to the traffic caused thereby were also estimated, it would be seen that our direct and indirect claims against Jove would bear a comparison with the historical Alabama Claims.

I.—ATMOSPHERIC ELECTRICITY.

I do not propose in this paper to discuss the cause or nature of atmospheric electricity. It is sufficient for our purpose to admit the existence upon the surface of our earth and in our atmosphere of that great form of energy called *Electricity*. To study the effects of *Heat* it is not necessary to discuss its nature, and the great laws of *Gravity* have been determined without reference to the inscrutable mystery of its causation. I, however, do not hesitate to assert it, not only as an opinion, but as a fact well substantiated by experience and by reasoning, fathered by the greatest lights of our science and taught by our leading philosophers, that electricity is no more matter than is heat, or light, or sound. Modern physicists know no such thing as the so-called electric fluid, *as a fluid;* that is, electricity does not exist as a mass occupying space, and moving from point to point in such a way as to justify the assertion so often made that "it enters here and makes its exit there." It is one form of energy, and therefore, necessarily *force* and not *matter*, displaying its effects in various useful, beautiful, and terrible ways. While the early theorists have imparted into our language terms based upon the hypothesis of a fluid—notably "current"—there is no objection to the continuance of these terms provided they do not convey to the mind erroneous ideas as to the nature of the force whose effects they symbolize. A current of electricity is a clear, well-defined term, raising in the mind at once an idea of its character; but it by no means implies the transference of matter from one point to another.

Thunder-storms are but gigantic repetitions of simple experiments. They are but elementary electrical phenomena, differing only in degree from those which cause the ordinary snapping spark from the machine, or the loud report from the Leyden jar. Electrical discharge, whether indicated by a *current*, by the *brush*, by a *star* or *glow*, or by a *spark*, depends simply upon the existence of two points at different potentials, separated in the first case by a conductor, in the latter cases by a non-conductor. In the case of the conductor, we have the ordinary electric current, and in the case of the non-conductor, when the difference of potential is high enough, we have the disruptive discharge, accompanied with its usual explosive and luminous results. In any case of electrical discharge, either that indicated by a spark from a lump of sugar, by the disruptive discharge of a Leyden jar, or by a flash of lightning, there must be two conducting masses in opposite electrical states, separated by a non-conductor or dielectric.

These masses may be two thunder clouds, or the earth and a thunder cloud, oppositely electrified, separated by the air, forming the simple conditions of an ordinary condenser.

The discharge, whether from a Leyden's battery, or from Heaven's Artillery, must be instantaneous and continuous along its whole path. The light we see is the effect of the discharge. It is indeed, as its color and as the spectroscope has shown us, simply incandescent matter. It indicates the path of the discharge and nothing more. When lightning is seen the danger is past. Persons who have been killed by lightning can have seen nothing of it. Their death must have been instantaneous. The placid state of their features is an indication of its painlessness. Persons who have been struck have stated that they have seen nothing and only felt a blow.*

The magnitude of the discharge depends upon the quantity of electricity present, and the distance through which it occurs. The path is prepared beforehand by induction. The particles of air or other matter in its path are raised to such a high state of polarization, that they are in a state of "tottering equilibrium," and the slightest acquisition of potential or diminution of resistance, either by approach of the conductor or increase of quantity, destroys this condition,

* Tyndall says:—"The nervous system requires a certain interval of time to become conscious of pain. The time of an electric discharge is but a small fraction of this interval; hence, as a sentient apparatus, the nervous system is destroyed before consciousness can set in. If this be true, and there are the strongest grounds for believing it to be true, death from lightning must be painless." (Notes, p. 16.)

and we have discharge with all the effects of light, heat, and mechanical energy. A ship sailing calmly over the ocean, a moving railway train, a horseman galloping home for shelter from the approaching storm, may prove the last straw to break this camel's back.

The air which we breathe is invariably found all over the surface of the earth to be in a state of electrification. It is usually positive in fair weather, except a thin stratum in contact with the earth. Its potential increases as we ascend; but even at the same place, its potential and character vary at times, particularly when thunder is heard in the distance.

It is usually assumed that the great masses of clouds, called thunder clouds, are themselves the generators or sources of these great charges of electricity which result in thunder and lightning. It is, however, very, doubtful whether this be so; but it is more probable that the clouds merely act the part of the coatings of a Leyden jar to accumulate and concentrate the charge in points. Clouds have even been known to be absent when a discharge of lightning has been evident; and discharges have frequently been observed to be repeated from the same cloud. Moreover, a very simple and well-known experiment shows that the charge of a Leyden jar exists, not in its coating, but in the dielectric which separates its coatings. In the same way a charge which terminates in a thunder clap exists in the air, and not in the cloud.

There is a beautiful experiment of Franklin's, which illustrates the accumulative action of a cloud moving through polarized air.

1. Apply a charge to A and draw it gently to A'. The charge will be found distributed.

2. Reverse the motion, the charge will again accumulate on A.

3. Charge the entire surface by a removable coating, then draw A gently to A'—discharge will take place two or three times during its motion.

A represents the cloud, B the earth, and C the air.

Thus a moving cloud may merely act the part of a carrier or accumulator of the charge which exists in the air.

Lightning is usually classified into *sheet*, *forked*, and *ball* lightning. *Sheet* lightning is merely the reflection of forked lightning, or the electric discharge which has occurred somewhere out of the field of view. *Forked*, called also *zig-zag* or *chain lightning*, is the light produced by the disruptive discharge between cloud and cloud, or between cloud and earth. *Ball* lightning is of a very different character. Many of the so-called "balls" are undoubtedly optical illusions, and Faraday himself stated that they were incompatible with what we know of electric discharge. "There may be balls of fire," said he, "but they are not electrical." Yet the evidence of balls of blue fire rolling along the surface of the sea, and suddenly terminating in terrible electric discharges over ships; masses of fire rolling along the ground towards buildings, ending in fatal discharge, and many other cases, leave it unquestionable that some such phenomenon as globular or ball lightning exists. Some have explained them to be balls of incandescent gas, rendered so by the discharge; but Mr. Cromwell Varley has recently offered a more acceptable explanation. According to him, ball lightning is a luminous spot on the earth, terminating a current or brush discharge from a negatively charged cloud. This spot moves with the cloud. Illuminated lines of force are projected from some point in the cloud upon the earth. He has been very successful in repeating the effect experimentally, and he suggests this fact as an explanation of the photographic images imprinted on the skin of persons struck by lightning.*

I quote from memory: "When after a serene sky thunder clouds form in the distance, the observer sees the clouds and the illumination of the lightning displayed before him as a magnificent picture; and what he often takes to be forked-lightning (*i.e.* the actual flash, and not the reflection of it) appears to run through the clouds in the most beautiful manner." "That which is thought to be the electric discharge is only the illuminated edge of a cloud, beyond and behind which the real discharge occurs. It is in its nature like the bright enlightened edge which a dark well-defined cloud often presents when between the sun and the observer, and even the moon also frequently produces similar appearances. In the case of its production by lightning and distant clouds the line is so bright by comparison with the previous state of the clouds and sky, so sudden and brief in its existence, so perfectly defined, and of such

* C. F. Varley, Trans. Royal Society, January, 1871.

a form as to lead every one at the first moment to think it is the lightning itself which appears." . . . . Hence many of the errors made as to the character, shape, and condition of the lightning flash.*

The discharge of a Leyden jar, of an induction coil, or that which is succeeded by lightning and thunder, invariably occurs along the line of least resistance. It has been found, in every accident which has been investigated, to follow the ordinary laws of the transmission of electricity, laws which are simple and thoroughly well known. This line of least resistance may be made up of metals, of bricks and mortar, of trees, or of animal flesh. Whatever, in fact, offers the least resistance will be the chosen path. It need not, necessarily, be a single track, for both in experiment with machines and with induction coils, as well as in the observation of the great experiments of nature, it is frequently found that the path is bifurcated, and often divided into three or even into four lines. Thus the electric discharge in the air is a simple case of the electric discharge between two electrified conductors which have acquired such a difference of potential as to break through the resistance of the dielectric which separates them, violently displacing its particles, and completely altering its physical features.

There is nothing hidden, mysterious, or unknown in the laws of atmospheric electricity. They are simple cases of the ordinary well-known laws which are as "familiar in our mouths as household words."

II.—ITS EFFECTS.

The effects of atmospheric electricity are perhaps better known than those of any other natural phenomenon. They have been principally studied in their destructive results upon ships, upon buildings, upon human beings, and—in our own particular sphere—upon the instruments employed for telegraphic purposes. The case of a ship is very different from that of a building, or an apparatus within a building. A ship is a prominent object—generally a conductor—situated upon a plane—the sea. It thus, if a thunder cloud passes near it, at once reduces the line of resistance between the sea (the inner coating) and the cloud (the exterior coating) of the condenser, determining discharge. Hence it is that so often it has been observed that a heavy black cloud is approaching the ship; and, without any previous warning whatever, a great flash of lightning or an apparent ball of fire has seemingly descended upon the ship, followed at once by an awful clap of thunder. On the other hand, buildings irregular form but an insignificant feature in the large area exposed to induction from a charged cloud. Trees and buildings take but a portion of the charges which in the case of ships have fallen in their whole intensity upon them. Except in the case of very prominent church spires, columns, etc., it is probable that the effects upon buildings are immeasurably smaller than upon ships. Again, in the case of human beings it is probable that but a small portion of the discharge passes through them; while in the case of telegraphic instruments the quantity of electricity which passes through them is still smaller.

From these cause, the methods that have been adopted for protection based upon the damage inflicted on ships, have probably led to the adoption of unnecessarily costly and superfluous measures to protect buildings and instruments.

We, in this Society, are more interested in the effects of lightning upon instruments, and upon the apparatus constructed for the transmission of telegraphic despatches, though we neither ignore nor neglect its effects in other fields.

The accidents that telegraphs suffer from might be divided into three classes:—

1. Those affecting the wires;
2. Those affecting the poles; and
3. Those affecting the instruments.

Each of these classes may be subdivided into those which are the result of the *direct discharge*, and those which are the result of *induction*. In the first case the wires, poles, or instruments, form a path or current for a portion of the discharge itself; in the second place they are influenced by currents which are induced by the approach, mersion, or sudden neutralization of charged clouds.

1. (*a*) *Direct Discharge.*—The direct effects are not nearly so numerous as the induced. In the case of open wires, the discharge forms but rarely anything more than an instance of the passage of a very powerful and instantaneous current. Cases have occurred, however, where this current was so great as to fuse and destroy the line-

* Faraday, vol. 2, p. 277.

wire; but such cases are very few and far between.

During the past season I can find but two cases where our line-wires—viz., No. 8 wires—have been absolutely fused.

(*b*) *Induction.*—It is evident that the accumulation of a charge upon a cloud converts it into a very powerful inducing body. As the cloud approaches the line it induces in the section of the wire nearest to it an opposite electrical state, and as this change of state is gradual, a current of sensible duration must be observed; but when discharge takes place and the cloud suddenly loses its coercive power, the wire as suddenly recovers its neutral condition, producing a powerful current in the opposite direction. Hence, during a thunder-storm, wires are pervaded by repeated currents which ring bells, demagnetize needles, throw apparatus out of adjustment, shock clerks, and make false signals on railway block instruments. During the construction of the Hoosac tunnel, two premature explosions of blasting charges were caused by these currents, producing serious and fatal results.

Not only the over-ground wires are affected, but those buried 2 ft. deep underground. I print as an appendix to this paper a very interesting correspondence which took place in the year 1854, between Faraday and Messrs. Latimer, Clark, and Culley, upon the demagnetization of needles upon the long underground circuits between London and Manchester, and very recently (July, 1871), while some joints were being made upon the new underground wires between Manchester and Liverpool, the jointer was alarmed by a succession of crackling sparks passing from the wires to his box, which was in contact with the ground.

2. In the case of poles, it has been found that when the pole has formed a portion of the path of the discharge, it has been, in the case of an unprotected pole, shivered to atoms, and one instance occurred where 20 successive poles were very nearly totally destroyed. Usually, however, a discharge, which has taken the wire in its path, divides itself amongst several poles, and cuts out, with the smoothness of a gouge, spiral grooves from the top of the hole to the bottom.

3. In the case of instruments, the effects have been:

(*a*) *From Direct Discharge.*—Currents of such a strength as to absolutely burst out the cases, burn the woodwork, and fuse the wire of the galvanometers and electro-magnets. An exceptional case of accident has arisen from the wires passing close to gas pipes and the discharge passing across the air fusing the pipe, lighting the gas, and setting the station on fire. Such cases are, however, rare, and have generally occurred at "intermediate" stations where no earth was employed.

(*b*) *Induction.*—The induced currents being instantaneous and very strong, demagnetize or reverse the polarity of magnetic needles such as those of galvanometers. This was a very prolific source of trouble in former days, but we have recently introduced induced needles which have almost entirely removed the evil. The needle inside the coil deflected by the working cement is not a permanent magnet, but a piece of soft iron temporarily magnetized by the influence of permanent magnets outside the coil; but even these external magnets are sometimes demagnetized.

III.—PROTECTION.

I will now discuss the measures that have been adopted for the protection from this destructive force.

1. As regards ships, the method adopted by the great authority, Sir William Snow Harris, has proved itself to be so efficient and perfect that no improvement has been required; nor can any be well suggested. Accidents to shipping have almost entirely disappeared; fishing smacks and small coasting ships are occasionally injured, but we never hear of an accident to the ships of our Navy, or rarely to those of our merchant service. Such vessels as have been struck, have been invariably unprotected.

2. In the case of buildings, however, there is much room for improvement, not only in the form of the conductor used, but in the extension of its adoption. The heavy cost of a system similar to that used for our ships, has probably had a serious influence in checking the employment of such protectors. I have known men pay from £40 to £50 for protecting their houses; but, as I contend, most unnecessary expense has been incurred in such cases. I hope to show that it is possible for a man to render his house as absolutely safe as a ship has been made, at an expense which may be considered trifling.

It must not be forgotten that a chimney lined with a thick layer of soot, up which a

current of heated air and volumes of smoke are ascending, and terminated with a mass of metal (the grate), is an excellent but dangerous conductor, for it ends in the room and not in the earth. Hence so many indoor accidents, and hence the duty of every householder, particularly in exposed positions, to protect himself and his family.

The conditions that determine a perfect lightning protector are:—

1. That it shall expose in some prominent position of a building a metallic point, and that it shall offer from this point to the earth a path of little or no resistance to the passage of the current. Hitherto, in accordance with the directions of Sir William Snow Harris in his application to ships, heavy copper rods, ropes, or plates of great expense, have been used; but I contend that a wire equivalent to the ordinary galvanized iron wire, known as No. 4, which is one-quarter of an inch in diameter, and used so largely for telegraphic purposes, is amply sufficient for any dwelling-house. The use of such an immense conductor is as though a man built a tunnelled sewer, where a small drain-pipe would do. My reasons for recommending telegraphic wire are these—when telegraph poles were first erected in this country, they were protected with lightning conductors made of No. 8 wire, led into a groove in the pole, and terminated at its upper extremity by a point. This practice was subsequently found to be expensive, and it was thought to be unnecessary. It was therefore abandoned, but at a later period it appeared that these earth wires or conductors were found to effect a very marked improvement in the working of circuits by removing the contact that occurred in wet weather between two contiguous wires. They caused the leakage from each wire to pass harmlessly to earth. Hence it is that on all our trunk lines poles are invariably supplied with these earth wires—not as a protection from lightning, but as a means of removing the disturbing contact that arises on badly insulated lines during wet weather.

Now, it is a fact worth recording that a case of a pole so protected being damaged during a thunder-storm is not on record; whereas scarcely a thunder-storm occurs without some unprotected poles being shattered to pieces. On examining a line of poles that extended from Basingstoke to Andover upon the London and South-Western Railway system, 15 per cent. of the poles were found to have been so struck. This line was renewed, and earth-wired, and since then not one single case of damage has occurred although many years have elapsed.

Several poles have recently been discovered which were considerably shattered for the first few inches of their tops; but from the point whence the wire proceeded to the earth, the poles were found to be thoroughly intact, the charge from that point passing harmlessly to earth through the wire. The cross-arms which are used for the support of the insulators and wires, are frequently found to be damaged as far as the earth wire, never beyond. Indeed, cases can be multiplied *ad infinitum*, where the No. 8 wire has been found sufficient to carry off the discharge harmlessly to earth. Moreover these wires unquestionably act as lightning protectors, for upon those lines which have been earth-wired, the damage to apparatus has been small in proportion to those which occurred on lines not so protected. Hence I consider that I am justified in saying that No. 4 wire, which is twice as massive, and offers half the resistance, is amply sufficient for the protection of such buildings as do not very greatly exceed our poles in height. I refer more particularly to dwelling-houses. However, as the height of buildings increases, and as we attain such heights as those reached by tall chimneys, chimney and church spires, larger wire than this would be advisable. Stranded wire from its greater pliability is preferable to solid wire. I can conceive no case where ½-in. stranded galvanized iron wire is not ample.*

The following precautions are necessary in fixing conductors to houses:—

1. The conductor must be solid and continuous from its gilded or platinized point to the ground, *i.e.*, there should be no joint unless it be a well soldered one in the whole of its path. Chains and link rods,† which which were used in the earliest forms of conductors, should be strenously avoided, and where existing, at once removed. Indeed, every investigation has shown that where damage has occurred to buildings protected by so-called lightning conductors,

* A ½ in. rod, 46 ft. long, conveyed harmlessly a charge, that destroyed the handsome spire of St. Martin's-in-the-Fields.

† At Monmouth I found a flat braided copper-wire rope used about one inch broad. Its continuity is very doubtful. It had points at every 4 or 5 ft. standing at right angles to the rope.

chains, linked rods, or other imperfect conductors have invariably been used.

2. Its connection with the ground must be sound and good: in fact in the language of the telegraphist, "it must make '*good* earth.'"

It may be connected with the iron gas or water mains; or be buried several feet in coke, or attached to metal buried in moist earth, or be carried down a well. *

3. Each conductor—if there be more than one—should make a separate earth if possible, and they should be all connected together, either above or below the surface. The lead roofing and all external masses of metal in the line of probable discharge should be connected with them. They should be periodically examined, not only to see that their points remain intact, but that the metallic continuity is perfect, and that they continue to make a good earth. The only effectual test of such perfection is to be made by testing their continuity with the galvanometer and current to see that they offer no resistance. The custom now is to fix them, and then to leave them to chance! They are never examined. An instance has been brought to my notice in the Island of Jersey, where the lightning protector of a church was found to be broken off at a distance of 2 ft. from the ground, and had been so for years; and the celebrated statue of Scott, in Edinburgh, was seriously damaged, owing to some mischievous person having removed the part which made connection with the ground, out of its receptacle. The practice adopted by many people to insulate these conductors, is evidently unnecessary, and it is equally absurd to carry them externally to their disfigurement—in the case of church spires, columns and chimneys. It is, however, better to carry the wire externally in the case of dwelling-houses, lest they pass too near to the lead gas pipes, which, being themselves good conductors, and soft metal, might be fused.

It is also assumed by some that electricity objects to go round a corner; and it is therefore urged that corners should be avoided; but it is evident, from the known laws of electricity, that this is an unnecessary restriction. The only point which one has to guard against is that there shall be no points or acute angles in the conductor, lest branch circuits be determined; hence the straighter and more direct its course to the earth the better.

The area protected by the conductor is a matter of much consequence, and it was said by a committee of the French Academy that this area should have a radius equal to twice the height of the conductor from the ground; but cases have occurred, owing to the bifurcation of the discharge, where buildings have been injured at a distance considerably less than this from a conductor. Hence it is thought safer to take the radius as equal to the height of the conductor. Thus, for small houses, one conductor is enough, but it is safer to attach one to each stack of chimneys. If it project a yard beyond, it is sufficient, for then it is within easy reach of inspection; a matter of some consequence when the principal function of the conductor depends upon the point with which it is surmounted being kept intact.

It is thought that with 30s. for materials and 10s. for labor, any intelligent man can, with these directions and precautions, safely protect his house from the destructive effect of thunder-storms.

I have recently had the pleasure of inspecting a plan adopted by Mr. W. H. Hyett, of Painswick House, near Stroud, Gloucestershire, by which he has succeeded in converting a 2-in. wrought-iron pipe, used for the ventillation of the drains of his house into a very effective lightning conductor. The wrought-iron pipe is carried from beneath the ground to a point 8 ft. above the top of the highest chimney. It is there surmounted with a vane having a sharp point some inches above its centre, the vane and the point being of copper. It is also connected with the lead coating of the roof. It appears to me to be an excellent and admirable system, worthy of greater adoption.

We will now consider the methods adopted to protect our telegraphs.

I have already pointed out that the system of earth-wiring poles has given us an excellent protector, but in addition to this most of our large stations are approached by gutta-percha wires in iron pipes underground, which form admirable lightning conductors, but, unfortunately, at the expense of the insulating covering. Hence the apparatus at our large stations very rarely suffer from injury.

* At Lydney Church (Monmouthshire) I found a lightning conductor of iron gas tubing leaded into a loose stone, which simply rested upon a stone paving.

There are only two forms of lightning conductors introduced into the instruments adopted by the Postal Department. The one applied to the single needle and Morse apparatus, and the other to the Wheatstone's alphabetical instruments.

It was observed that when wires were knotted or tied together, electricity of high potential was discharged across this knot in preference to going through the loop. When a discharge takes place through a non-conductor, such as dry air, at the moment of discharge the resistance along the line of discharge is so far reduced as to allow the passage of the greater part, if not the whole of the current, so that, in point of fact, at the moment when the discharge occurs, through a layer of air or other elastic medium, a conductor of very low resistance is formed. Hence, as a current divides itself in inverse ratio to the resistance opposed to it, the greater portion, if not all, flies across the knot or shunt. This is only an example of Faraday's well-known experiment, in which a long wire is so bent that two parts, *a b*, near its extremities, approach within a short distance, say ¼ in. in air. If the discharge of a Leyden jar be sent through such a wire, by far the largest portion, if not the whole, of the electricity will pass as a spark across the air at the interval, and not by the metal.

Mr. Cromwell Varley, in the old form of single needle coils, simply twisted together the two ends of the coil wire before they were attached to their proper terminals, and it was found that this acted as a very efficient protector, the charge flying across the short interval in the twist in preference to going through the coil. In order to make this system more mechanical and general, two wires of different colors were laid together and placed around the barrel of a small boxwood reel and applied to the ends of the coil. The wires themselves were still further protected by being drawn through melted paraffine. This last process has, however, unfortunately destroyed their efficiency, and experience has shown that these so-called protectors have become no protectors at all. Indeed, they only act at their own expense, for though they may save the coils from the first discharge, they are themselves destroyed. A succeeding discharge must infallibly destroy the apparatus. This is the method adopted up to very recently in the Needle and Morse Instruments, but it has been partially abandoned for that in use in the alphabetical dial instruments, which is known as "S. A. Varley's carbon or 'lightning bridge' protector." The wires of the coil are attached to the termination of two insulated piecess of brass fitted in a boxwood cover, the opposed ends of which are pointed and inserted 1-20th of an inch apart in a chamber filled with a mixture of carbon and non-conducting matter in a fine powder, the preparation of which remains a secret with the firm who conceived and supply the apparatus. The protector acts as a shunt,* which offers such a resistance compared with that of the coil, as to prevent any appreciable diminution in the strength of the working currents; but it is assumed that in the case of the discharges of atmospheric electricity the protential is so high as to overcome this resistance, and convert the bridge into a path for the discharge, in preference to the coil. They have sometimes caused inconvenience owing to their particles becoming polarized, and forming a conducting line of low resistance, and thereby practically placing the instruments in short circuit. This is remedied by simply shaking, but it certainly is a defect of this form of apparatus.

Experience has shown that this carbon protector is not very efficient, and it is questionable how far it is based on correct principles. The chamber being filled with a partially conducting substance, prevents the peculiar action of the discharge through a gaseous medium which I have endeavored to explain above, and it being simply a shunt, it prevents the charge from being dissipated or passed to earth. I hold it essential for an efficient lightning protector to make use of the earth so as to form a path for the charge direct to earth, without simply leading it off to another place to possibly increase its destructive effect, as is done in these shunt protectors.

It will be seen that we in England protect our instruments. I think I am right in saying that in all other administrations the stations themselves are protected. It must be acknowledged that our system has proved a failure. It will be interesting to

* Mr. Varley says: "Practically no electricity would pass from a fifty cell Daniell's battery through loose powdered black lead or wood charcoal; but a current of 200 or 300 cells would arrange the conducting particles by electric attraction and freely pass over; while a current of 600 cells would pass across a considerable interval of the ordinary dust met with in rooms, consisting chiefly of silica, alumina, and more or less carbonaceous and earthy matter."—*British Association.*

learn the experience of others. Until this year, the accidents in England have been trifling. In the Electric Telegraph Company, only 3 per cent. of their instruments suffered. This year is, in reality, our first year's experience in the Postal Telegraph Department—the previous years having been comparatively mild; and though so much severity can scarcely be expected to recur, it is well to be protected against its repetition.

The postal Telegraph Department has greatly increased the number of instruments employed in this country. The number of stations have increased from 2,932 to 5,174, the number of instruments from 2,175 to 8,500. Its extensions have been erected into districts hitherto unoccupied by telegraphs. The area of the telegraphs exposed to the influences of atmospheric electricity has thus become greatly enlarged, and consequently the damage done has been greatly increased. In the days of the Telegraph Companies it was found unnecessary to protect their instruments, for the cost of applying any protective apparatus there would have far exceeded the damage done. Now, however, the matter has become more serious, and not only has the necessity of the employment of protective apparatus shown itself, but also the necessity of improving all such protective apparatus as have hitherto been adopted.

We have been more successful with our submarine cables, which are protected with another very ingenious form of lightning protector, also from the prolific house of "Varley." In this instrument an earth wire and the line wires are fused into a glass globe, which has been made a partial vacuum, and which, as is well known, offers a ready path for the discharge of electricity of high potential.

The discharge of electricity across air, depends not only upon the distance which separates the opposite points, but upon the density of the air. The closer the air approaches a vacuum the less its resistance. Hence the efficiency of this "vacuum" protector.

They have frequently acted with great efficiency, and have given great satisfaction.*

* At Talybont, on the Anglesey shore, on July 7th, 1872, one of the Manchester-Dublin wires were found to earth, owing to electric discharge having fused together the two points (line and earth) of a vacuum protector, and burst the glass globe. In detaching the wires from the box they came apart. The cable was undoubtedly saved.

In some of our cable nuts an additional security is obtained by inserting a spiral of fine platinum wire of 2 or 3 ft. in length between the line and the protector, and even this has been supplemented by the insertion of a form of protector in which a flat brass earth plate is separated from another plate in connection with the line, by a thin slip of paraffined paper. The latter has also proved itself to be a very efficient form of conductor, and, on examination, it is frequently found that the paper is pierced with small holes, giving the indication of carbonization, an evident proof of their having been effective in drawing charges from the wire, and passing them harmlessly to earth. The paper in itself offers an almost infinite resistance to the passage of the working currents, but the air in its interstices is easily overcome by the high potential of atmospheric discharges. It is thus impossible for the wire of the cable itself to be raised to so high a potential as to endanger the dielectric coating until all three protectors fail to act. There has not been a case of a cable so protected breaking down, while there are cases on record of unprotected cables being injured.

It must not, however, be forgotten that however valuable lightning conductors may be as protectors to our apparatus, they also produce numerous faults of their own. Thus, during the past year a large number of faults have been brought to my own knowledge produced by the very few conductors under my charge. If their use becomes more general, the faults they produce must increase, so that in remedying one evil we generate another.

In India where the thunder-storms are far more intense than in this country, and where scarcely a day elapses, during certain seasons, without the occurrence of lightning, very efficient means of protection have been adopted. Accidents are very rare. Every office is protected with simple earth plates, separated from line plates by a thin layer of air, the interval being maintained by thin ebonite washers. The line plate is sometimes studded with points secured into it, and the line wire is connected to it through a small coil of platinum wire. The posts also when not of iron are for a mile on each side of an office protected with rods projecting above their tops. When iron posts are used, this protection is not needed.

The effects of atmospheric electricity in America are well illustrated by the follow-

ing extract: "During a recent storm at Cincinnati, Ohio, the lightning followed the wires into the office, and at each flash concentrated in a sheet of flame on the switch board, producing a concussion similar, at first, to the discharge of a score of rockets, quickly followed by two reports as loud and distinct as the discharge of a six-pound cannon, succeeded in turn by a volley of musketry. It became necessary to disconnect all the wires, and keep them disconnected about an hour and a half. Some of the operators, who were unused to such severe electric displays, supposed at first that the 'day of reckoning' had come."

IV.—PREVENTION.

I have lastly to speak of the prevention of lightning discharge. I have shown that electric discharge is simply due to the fact of two points separated by air, being raised to such a difference of potential that the resistance of the air cannot restrain their neutralization across it. Now, if we prevent the increase of potential by dissipating the charge as it collects, we effect this object. This is the function of points. Points prevent the accumulation of charge. A pointed body, such as a needle, directed towards a charged conductor, dissipates the charge at once. A pointed conductor directed towards a charged cloud, dissipates the charge in its immediate neighborhood quietly and silently. If lightning is seen to play about the top of a conductor, it is a proof that it is out of order, and does not act properly. A glow or brush may be seen, but nothing more should be visible. Thus it is that the chief merit of a lightning conductor consists in the action of its pointed end, and hence the greater care should be taken to see that its point is maintained intact. Points are sometimes fused by powerful discharges. A properly constructed conductor may be said to prevent electric discharge within the sphere of its action. But it does not prevent thunder and lightning. When we consider the distance of the cloud and the area of its surface, the height of a building vanishes in the general figure. Hence the discharge may occur very near, though not within its protected area.

Since the potential of the atmosphere increases as we ascend, and we place at the top, say of the spire of a cathedral, a pointed rod, we connect two points, the earth and the atmosphere, of different potentials by a conductor. The result must be a current. This current constantly flows in one direction. Its strength will vary with the potential of the atmosphere. The results must be at the point of juncture with the ground, electrolytic action, and destruction of the conductor. I went to Llandaff Cathedral to test this theory. The conductor is a small copper stranded wire fixed externally by iron spikes. I took hold of it with my hand, and it came out of the ground most readily. It was entirely corroded at about a foot below the surface. The strands of the copper wire were eaten away to fine needle points, in a way with which submarine cable engineers are fully acquainted. It was bright and clean, in dicating clearly the passage of a current. Here is fresh source of danger; but it is mitigated, if not cured, by making earth with as large mass of metal as possible, such as the gas or water system of a town. The electrolytic action is thus spread over such a surface that its effect is infinitely small. Lightning conductors, however, of all kinds require periodical examination. They will not last for ever. Their points should be maintained bright and clean, their electrical continuity should be kept perfect, their joint should be sound, and their earths should be good. If any of these points be neglected, the conductor fails to do its duty, and accident is the result. One of the brightest seeds of scientific thought is thus by ignorance and neglect allowed to fall into desuetude, and that which was erected for our protection may become a source of danger.

THE A B C PROCESS.

From "Engineering."

The sewage question has been treated almost *ad nauseam*. Irrigation, filtration, and precipitation have been the "watchwords" of its different "doctors" for about 50 years. Thanks to the late Dr. Faraday, the subject was made one of public interest in 1854, when the state of the Thames at Hungerford Bridge was something fearful.

He described in a letter to the "Times," how, tearing up his card, the appearance of its surface was lost by immersion of only 1 in. The banks of the Thames, at that date, between Hungerford and Westminster Bridges were simply a mass of *Gordii*, intwining each other in a Gordian Knot. These animals extended also to the Southwark side of Waterloo and Blackfriars Bridges, whence, in 1849 to 1852, the chief water supply of the southern side of the metropolis was obtained. In those years we have repeatedly *seen* the supply at Walworth replete with worms, etc., and the *smell* of gas tar on the water sent into the house tanks was an indication that the turncock had done his duty. Samples of the water which were exposed to a lime-light, condensed by a 9 in. lens, were perfectly impervious to light. Within our experience samples drank between London and Battersea Bridges were scarcely in a better condition. The sewage was, of course, charged with these faults, for at that time the north and south of the metropolis sent all the refuse into the Thames, the *Maxima Cloaca* of London.

Liebig was one of the first to advocate the utilization of sewage, but his first ideas gave little encouragement. Then at the zenith of his popularity, however, any expression of opinion on his part was taken as absolute authority. Hence arose the theory that by irrigation, or by chemical precipitation, sewage might be made to produce results of the most valuable nature for agricultural purposes. It is rather remarkable, however, that every chemist who has advocated the latter scheme has ignored the fact that *ammonia* is not practically precipitable, except by means of a reagent, the expense of which would render the recovered ammonia more expensive than gold. Failing the ammonia, phosphates were had recourse to as designative of the value of sewage manure; and so an antagonism was generated between nitrogen and phosphoric acid, leaving another opening for the investment and loss of capital.

The most prominent schemes now before the public for utilizing sewage, are the irrigation farms, as carried out at Barking, Romford, Croydon, Rugby, etc.; the A B C Phosphate Sewage; Anderson's and Manning's patents; and a combination of all these or some of them with filtration. The financial history of many of these concerns is highly instructive. In respect to the proposed plan of using the sewage of the northern side of London for irrigating the Maplin Sands, it seems that the Company formed for that purpose have forfeited above £20,000 to the Metropolitan Board of Works through the impossibility of carrying out their plan, apparently for want of capital.

The Warwick (not the Earl of Warwick's) irrigation farm seems to have been practically a failure, and is, we believe, now given up, or will shortly be. A personal inspection of the Barking and Rugby farms, during June and August of this year, lent no features of encouragement in respect to irrigation. Turning to the chemical processes, we find that the Native Guano Company have spent nearly £100,000 in four years by endeavoring to establish a scheme, that, whatever may be its merits, has been generally condemned for reasons that we shall impartially and carefully investigate. The shares of that Company, and of the Phosphate Sewage, have been subject to violent fluctuations in the money market. Those of the Native Guano Company have been quoted at above £40, but are now, or recently, at a little beyond par (£5 was the original price of the shares), while the Phosphate Company has fared still worse at the hands of the Philistines of the Stock Exchange. We have every reason, gathered from a variety of sources, to express the opinion that *all the present means suggested for the profitable utilization of sewage for manure will prove lamentable financial failures.* Hitherto they have done so, as is too well known to all the shareholders, and we do not see, unless some extraordinary discovery is made in science, how the diluted state of the excreta, as found in the sewage of all our large towns, where water-closets are employed, can be rendered of any profitable application. Circulars, prospectuses, etc., constantly sent forth by these rival companies, state a precisely opposite opinion, but the balance sheets of such companies confirm our statement.

Having thus given a general review of the "principles" on which the various sewage utilizing schemes of the present day depend, we shall next draw attention to the chief patents, etc., that pursue the chemical treatment of town sewage—that is, the purification of the sewage of water-closet towns, and the so-called extraction of a valuable manure from such sewage.

Foremost of these methods is that of the A B C process, as carried on by the Native Guano Company, at Leeds, and at Crossness, near London. Its history may thus be briefly stated, partly as described by two of the earlier patentees. In or about 1854 a gentleman of the name of Dover attempted to utilize sewage by chemical precipitation. He indirectly stated his object to Messrs. Sillar, who entered on the project with great spirit. In his public lectures Mr. W. C. Sillar has described his inventions as really derived from instructions found in the Book of Deuteronomy, so far as relates to the use of blood, the most essential feature in the A B C process, and that, in fact, on which the legal value of the patent depends. The term A B C was derived from the names of the ingredients employed in the process, viz., alum, blood, clay, and charcoal. According to the views of the original patentees, with Mr. Wigner, who was engaged as their consulting chemist, it is absolutely essential that the blood of an animal, preferably of the bovine species, and not of the porcine (pigs being Mossaically unclean animals), should be received from the animal at the time of death, the blood being "poured on the ground," but practically received by, and incorporated with, ordinary clay. The theory which was, and we believe is still maintained by the patentees, embraces the idea that the vitality of the animal is thus conservated and eventually conveyed to the plant per the Native Guano. When Darwin, Huxley, and other men of science give vent to theories on vitality it is not for lesser mortals, such as ourselves, to expound the laws of biology, physiology, *cum multis aliis*. There is one fact that we may safely affirm. It is, that no one has yet seen the production of a live chicken from a cold boiled egg. In drying the manure, the Native Guano Company employ heat far exceeding that of the coagulating point of albumen. Hence, the albuminous and albuminoid constituents of the blood they employ must have pased into a state of coagulation, and consequently lost all chance of vitality-propagation.

There is one point, however, in fact, not theory, which crops out in reference to blood. If this be incorporated with clay, so as to make a kind of paste, the mass, instead of putrefying and becoming offensive, may be kept in summer at a temperature of 80 deg. to 84 deg. Fahr. for more than a fortnight without giving the slightest sign of smell. Perhaps if the Company had limited their theory to this easily established fact, they would have avoided much obloquy. In practice, however, it has been found that for all purposes of precipitation, the blood may be replaced by other albuminous and albuminoid substances, such as glue, fish skins, isinglass, etc. Now many of these have been long in use for fining purposes, as in making coffee, and fining beer and wines. Here practical philosophy supplies facts, instead of the curious theory we have explained; at all events, so far as the purification of sewage and the production of a good effluent are concerned.

But besides the blood, a variety of ingredients is employed in the A B C process. In the original patent granted to the Messrs. Sillar and Wigner, a mixture of chemical ingredients was specified, of which the proportions preferably used were as follows: Alum, 600 parts; blood, 1; clay, 1,900; magnesia, 5; manganate of potash, 10; burnt clay, 25; chloride of sodium, 10; animal charcoal, 15; vegetable charcoal, 20; and magnesian limestone, 2; with about 20,000 parts of water (not specified). It is stated in the specification that "the quantity required will be about 4 lbs. of the mixture to 1,000 gallons of sewage." It is added, however, that, "in many cases, it is preferable to mix the above compound (that is the solid ingredients and the blood) with a small quantity of water, and add it in a liquid state to the sewage." A claim was made in this specification, which is utterly invalid, inasmuch as, to our own knowledge, this was an operation in 1854; such clause is thus stated: "Thirdly, the addition of an acid to the mud in order to retain ammonia and fit it for use as a manure." This was recommended in 1854 to Mr. Dover, substituting sulphuric acid for "muriatic" acid (hydrochloric), that he had then employed. Subsequent patents were taken out by the Native Guano Company, in the name of Mr. Wigner, dated February 8, 1870, and May 12, 1870. In the latter patent an amusing series of charcoal products is advised for employment beyond that of the blood, which, if really patentable (if we may employ the phrase), would leave little, antecedent or subsequent, for other persons to secure. But the looseness of definition in regard both to quality and quantities of each ingredient, would serve for the trial of

a *cause célèbré* possibly exceeding in interest the celebrated paraffine case of James Young, involving the question whether the Torbane Hill mineral was really a coal or a shale.

The latest patents taken out by the Native Guano Company are dated December 30, 1870. The chief clause in this is "the use of albuminous and albuminoid substances in addition to the substances" (named in the specification we have already quoted). The rest of the claims depend on accidental circumstances for which provision can be made according as necessity requires, but which have practically not been carried out to the extent proposed in the patent.

ALEXANDRIA HARBOR.

From "The Engineer."

Time was, in the Grecian period of Egyptian glory, when the city of Alexandria was mistress of the seas, the great emporium of the commerce of Europe and the East, boasting the possession of a harbor that none could surpass, with its Pharos, or lighthouse, of white marble, towering, as some historians assert, to a height of 400 ft. above the sea, serving as a pillar by day, and lit up with its beacon fire as a guiding star by night to the mariner entering the ancient port.

Of the great and glorious city, its harbor, and its light, nothing now remains but an arid and desolate waste, heaps of *debris* of building materials, broken pottery, sand and stone, with here and there the remnants of brick-built walls and an occasional piece of more substantial work; or the broken shaft of a marble column cropping out from the piles of rubbish. The old harbor is silted up—the lighthouse is gone. A new town has arisen on the extreme western end of the site of the grand old city, and the commerce once so vast, then almost annihilated, again struggling for a bare existence, burst at last into renewed life under the administration of that regenerator of modern Egypt, the strong-minded Mahomet Ali. Rapid has been its rate of increase, and Alexandria is once more a flourishing city. Commerce again crowds its harbor, the Indian passenger traffic all centres there, and with returning prosperity and a firm and able Government in Egypt, its mixed and varied population from every nation under the sun is putting forth its energies to accommodate their harbor and their city to the requirements of a European standard.

The opening of the Suez Canal has not damaged the trade of Alexandria; it has diverted some traffic, but it has brought more. The development of the country has been rapid, and it is as rapidly progressing. The export and import trade of two million tons a year, brings into the harbor from 3,000 to 4,000 vessels, the majority of them large sea-going steamers, of which 50 to 100 may often be counted there together. But the ships of our day are not as those of old. A Roman trireme was a plaything to a Peninsular and Oriental mail steamer, and the depth of water that sufficed for the one will not float the other; so it happens that the old harbor has long been abandoned, and the bay to the westward of the Mole, though more exposed, has been adopted. Here we find a depth of 5 to 10 fathoms of water close inshore, intersected outside by numerous reefs and shoals which render navigation difficult and dangerous, only possible by daylight, and even then requiring the most careful piloting. Moreover, as these shoals and reefs are the sole defence to the shipping inside, artificial protection and the improvement of the means of ingress and egress have become an absolute necessity.

Matters of this kind in Egypt, as elsewhere in the East, do not advance very rapidly, and so it comes to pass that ten years have been consumed in attempted arrangements to mature some scheme. First the French engineers tried their hand, then native talent dabbled, and then English enterprisers offered to find the money conditionally on having conceded to them the right to levy dues. This, after some delay, was declined, the Egyptian Government announcing their intention to take up the matter themselves. English engineers were consulted, English capital was enlisted, and a contract for the execution of the works was entered into in 1869 with Messrs. Greenfield & Co., or in reality, Messrs. Kennard, Elliot & Maclean.

The works are to consist of a breakwater

about a mile and a half long, running in a pretty direct line from the lighthouse on Eurotus Point towards Mex, with an opening of about half a mile next the lighthouse for the use of native coasting craft, and reaching to within a mile or so of the shore at the Mex end. This breakwater is to be constructed after the plan of that at Port Said, by simply tipping into the sea immense blocks of concrete or beton. This work being the most important, is being first done. The area inside will be rather over 15,000 acres, but this is being cut up by an inner mole or pier, that, from its position, can be of but little use, and if finished—which we trust it may not be—will so contract the harbor space that there will not be accommodation for even the number of ships that now lie there. It is put in the wrong place and pointed in the wrong direction, and we trust that wiser counsels may yet, ere it be too late, prevail. Inside all that, quay accommodation, now so much needed, will be found by filling up the foreshore.

Of the works now in progress the most interesting part certainly is the vast establishment at Mex, some four or five miles along the coast, where the manufacture of the concrete blocks is carried out, where 800 tons of stone, sand, lime, and water, are daily converted into 40 blocks of 20 tons each; and as these are required to lie for at least ten weeks to set and harden for use, the number of these large masses lying on the ground at one time is not less than 2,500, or 50,000 tons.

Each block contains 10 cubic metres, that is to say, being about 10 ft. long, 6 ft. deep, and 6 ft broad. The limestone is quarried on the spot by large blasts of gunpowder. A small hole is drilled in the hill side, and, by means of sulphuric acid and water, a cavity capable of containing some hundredweights of powder is formed, and, being charged and fired by the electric fuze, brings down several hundred tons of stone. The sand is obtained from a hill a mile and a half further west. The hydraulic lime (Thiel lime) is brought from near Marseilles, and 34 cwt. of this is put into each block. These blocks are arranged in five long rows over nearly a mile and a quarter of ground, each row spanned by a travelling crane, the whole area covered with 5,000 to 10,000 tons of rails and perfectly levelled; it forms altogether a sight to gladden the heart of any engineer. Each row communicates with the others by many turn-tables and cross roads. Ten to twelve locomotives are constantly employed bringing and moving the materials, or taking away the blocks when sufficiently set for use. As fast as these are removed wooden frames are erected; a travelling crane bearing aloft a 10-horse power engine takes possession of the vacant site. Thirty-four hundredweights of Thiel lime are rapidly lifted to its topmost story with the necessary amount of stone and sand; iron pipes laid along each line of blocks supply the necessary water, and the mixing machine aloft grinds away, and in a very short time the mould is filled, and a twenty-ton block of concrete lies in a plastic state below! After the lapse of a few days the wooden mould is removed and the mass allowed to lie for ten weeks to harden ere it is considered firm enough for removal. When that time arrives a travelling crane, worked by its own engine, moves over the spot, the block is lifted like a plaything upon a truck, and drawn away to the place of shipment, where, in a convenient little harbor, specially constructed for the use of the works, the lighters are loaded with five or six blocks each. Other lighters receive their cargoes of huge pieces of rubble limestone, and the whole being towed out to sea to the site of the intended breakwater, the chocks are withdrawn, and the masses, with a mighty rush, precipitate themselves into the water. No attempt is made to deposit them with any regularity, they take their own bed, and as the mound thus formed rises to the surface, so that the tipping lighters can no longer float, a magnificent steam derrick comes along, and picking up the blocks deposits them in a rough sort of order, and piles up with more or less regularity a mound whose top reaches 10 ft. to 15 ft. above the sea. The breakwater when complete will, it is estimated, have consumed 35,000 of these blocks, besides large quantities of rubble stone. Fifteen thousand are already made, and the work of construction proceeds at the rate of 40 a day. The manufacture and deposition of 800 tons of concrete daily, where every ounce of the material has to be quarried, handled, and loaded many times over, involves no small amount of labor. Two thousand Arabs are assisted by a dozen locomotives and some hundreds of trucks and wagons running over 50 miles of railway. Forty other steam engines, stationary and moving, contribute their quota

to the task, which a dozen lighters, six steamers, and the great steam derrick complete. To maintain such an establishment in working order necessitates a repairing shop of no small dimensions, the extent of which in a foreign land those accustomed to such works can best appreciate. The staff of engineers and officers for the direction and management of the undertaking is in proportion to the rest of the work, and altogether the capital invested in plant alone cannot be far short of £200,000. The whole of the machinery and arrangements are the most perfect of their kind, everything that science can suggest or engineering talent can devise is there provided; and an enterprise as vast as that at Plymouth or Portland will be completed in one fifth of the time, in a way that reflects unbounded credit on British enterprise and skill, calls forth the admiration of a visitor for the master mind that can direct, and the able officers that can so well execute such an undertaking in a manner that the courteous and hospitable reception accorded to us by Mr. May, the chief engineer, and the ready intelligence of his principal assistant, Mr. Brown, is certainly not likely to dim.

ON THE METALLURGY OF MANGANESE.

By HUGO TAMM.

From "The Chemical News."

This paper will raise much criticism; and anything of value which it may contain will be disputed, so that very little credit will be given to me who claims the laying down of the basis of the metallurgy of manganese, which, up to this day, had no existence.

The names of Pliny, who described manganesia as a black magnesia; of Scheele, who recognized it as a distinct earth, and of Gahn, who isolated manganese, will be thrown at me with alacrity, and I am not quite sure that elaborate articles will not be published establishing as undeniable facts that Tubal Cain knew the use of fire, that lime, fluor-spar, and glass were known to the ancients, and that loam and plumbago are in constant use in the arts. Yet in spite of all this I will feel quite confident that, until now, the metallurgy of manganese did not exist, and that I am the first to establish it on its true basis.

I had a great many practical difficulties to overcome before I was enabled to bring it to the simple form under which I now describe it. I have rendered it almost as simple as the metallurgy of iron; so far, at least, as is consistent with the nature of manganese, a very oxidizable metal. But although I have great faith in the progress of industry, I must confess that I do not think that under present circumstances, and with the common substances at the disposal of chemists and metallurgists, the metallurgy of manganese can be simplified or improved upon.

To do the one or the other, new and inexpensive materials which do not exist at present would have to be used, and I repeat that with the actual means at the disposal of industry, the metallurgy of manganese has reached in my hands the last degree of simplicity and perfection which it could attain. However, others will judge. The metal obtained by the new process is not pure manganese—it is to manganese what cast-iron is to iron, and I will henceforth call it cast manganese. But it is prepared with common materials, and the superiority of the process consists in this, that with a given manganese ore the cast manganese is purer than the corresponding metal extracted by another process, and lastly, it is obtained with greater facility, greater security, and at less expense than with ordinary means, and what is most important of all, it may be prepared in unlimited quantity.

If I have been thus successful in creating, so to speak, the metallurgy of manganese, it is because my endeavors were directed from the first to the reduction of manganese ores in presence of a flux. I knew this to be the knot of the question, and I was quite right.

The reason of this will be obvious after I have described the nature of the flux used for the smelting of manganese, and the nature of the slag obtained after smelting.

I will divide this paper into six parts:

1. Preparation of the fluxes.
2. Preparation of the crucibles.
3. Smelting of manganese ores.
4. Refining of cast manganese.
5. Properties of cast manganese, and analyses of the ore and of the metal.

6. Docimastic assaying of manganese ores.

PREPARATION OF THE FLUXES.

Two fluxes are required for successful and really practical operations in the smelting of manganese. One of which I will call flux No. 1, or white flux, and which is obtained by mixing well together common ground bottle glass free from lead, quick lime, and fluor-spar. The following are the exact proportions to be mixed:

Ground glass	63 parts.
Quick-lime	18½ "
Fluor-spar	18½ "
	100

This flux is the original flux from which the others are made, but it is used also *per se* to add to the fusibility of the others.

The second flux, flux No. 2, or black flux, is theoretically required for the smelting of manganese, and it can be used in practice. It is formed by mixing:

Flux No. 1 (white flux)	61½ parts.
Native oxide of manganese, of good quality	35 "
Very fine charcoal powder, soot, or lamp-black	3½ "
	100

This flux may be used just as it is obtained after mixing. But it is best to incorporate the mass by adding enough of an oil to form a paste, and heating the whole at a high temperature in a closed crucible. The oxide of manganese is reduced to the state of protoxide, the flux assumes a fine olive green color. It may be ground and kept for any docimastic or metallurgical operation on manganese.

But on the whole, the best and safest mode of operating is the following. A mixture is made of:—

Flux No 1	34 parts.
Lamp-black, or soot of good quality	5½ "
Peroxide of manganese, native of good quality	60½ "
	100

And it is smelted as will be hereafter described; 17½ parts of cast-manganese are obtained, and the slag which presents a fine olive green color, is ground. It is saturated with protoxide of manganese, to which it owes its color, and it forms an admirable flux, either for the smelting of manganese ores or for their docimastic assaying. I shall henceforth always design the flux thus prepared as flux No. 3, or green flux.

I have not made a full analysis of this flux, which might be interesting in some respects, for the reason that I expected no practical result from such an analysis, or, indeed, no theoretical considerations of real value. The flux contains of course all the elements of flux No. 1, *plus* a large amount of protoxide of manganese, *plus* a certain quantity of the oxide of iron and the silica and earthy matters contained in the manganese ore, and we shall see, by and by, how this slag, for it is nothing else but a slag, has acted during the smelting. When this flux is prepared specially for docimastic purposes, it should be made with the native oxide of manganese. When once the green flux has been obtained, the extraction of manganese presents no further difficulty, because it can be used over and over again, providing the oxide of manganese reduced is of tolerably good quality, and introduces no injurious material into its slag. This slag, being saturated with protoxide of manganese, is as good as the original flux, and the only improvement which it requires is the addition from time to time of a little white flux, to add to its fusibility, which might be slightly impaired by the incorporation after each smelting of the gangue of the ore.

Green flux is formed of three distinct parts: glass or dissolving agent, to which lime may be added; fluor-spar, or fluidifying agent; and protoxide of manganese and lime also, or refining agents.

I will not dwell at length on its chemical properties, but I will enumerate them in a few words.

(1.) It becomes very fluid at a high temperature, and allows the metallic grains to collect easily in a mass.

(2.) Its silicates, besides dissolving the earthy matters of the gangues, add some silicium to cast-manganese, and add to the fusibility of this metal.

(3.) The silicates form with protoxide of iron a silicate not reducible by carbon.

(4.) The protoxide of manganese with which it is saturated acts as a refining agent, and it prevents cast manganese from absorbing more than a certain proportion of silicium, of carbon, of iron, or of earthy metals.

(5.) Its chief property is that it does not dissolve oxide of manganese, and that it allows the whole of the oxide mixed with it to be reduced to the metallic state.

These few facts of importance once established and understood, we will proceed.

PREPARATION OF THE CRUCIBLES.

My successful efforts in discovering a perfect flux for the reduction of manganese would have been valueless had I not succeeded in overcoming another apparently insuperable difficulty. At the high temperature required for the smelting of manganese, no crucibles could stand the flux, and they were all destroyed. I tried pots of every description, even the best plumbago crucibles, but none would stand the molten flux.

I could not think of using pots lined with charcoal in the usual fashion, because this kind of lining is not practicable on a large scale; but the following plan which I devised is so simple and so effective that not only is every difficulty removed, but special advantages are attached to its use.

Three parts of plumbago and one part of loam or fire-clay are mixed together, and made into a thick paste with water, and the crucible is as equally as possible lined with this paste, which holds firmly to its sides. The thickness of the lining varies with the size of the crucibles, but with the largest crucibles it should not exceed half an inch.

The properties of this lining are worth mentioning.

(1.) It stands the destroying effect of the flux to perfection.

(2.) A crucible so lined may be used immediately after it is lined, provided it be gradually heated.

(3.) After smelting, neither flux nor metal adheres to the lining, and both may be extracted quite easily by reversing the crucible and taping it gently.

This last fact is very important, since both the crucible and its lining can be used several times. Still, after each smelting the lining wants repairing slightly with the mixture of loam and plumbago, made into a somewhat thinner paste than at first, and the outside of the crucible must be repaired with a little thin fire clay.

I think it is just as well to give these apparently tedious details, which have their importance; but should I omit anything, with a little practice the best modes of working would soon be found out. The discovery of a flux, in presence of which manganese could be reduced, and of a crucible which could stand the destroying action of the flux, were the two real difficulties to be overcome; the remainder presents no real difficulty.

SMELTING OF MANGANESE ORES.

The proportions which will be given are those which were found to succeed best with a manganese ore of good quality, and they do not admit of much alteration; but still the general process is of course open to slight modification, according to circumstances and to the nature of the ore used.

Any crucible which will stand a white heat for several hours without softening can be used. It is lined with loam and plumbago, as I have previously described, and then the following mixture is introduced into it:—

Native oxide of manganese of good quality	1000 parts.
Lamp-black or soot of good quality	91 "
Green flux	635 "
Oil in sufficient quantity to merely wet the mixture.	

Any kind of oil is good enough for the purpose. The mixture must be made shortly before introducing into the crucible; for if it is left standing for some hours, especially in an open vessel, it is apt to catch fire, and is then unfitted for smelting. Should this occur, the addition to the burnt mixture of about 45 parts of lamp-black or soot and some more oil, would remedy the accident. But it is only after standing for some eight hours that the mixture takes fire.

The mixture is introduced into the crucible and slightly pressed in, and a round cover of thick wood is placed over it. It is carbonized during the smelting, and forms a charcoal cover which protects admirably the mixture from oxidation, and it can be used several times.

The clay or plumbago cover is then placed over the crucible, and the joint is luted with a little thin fire-clay. A small aperture is kept to allow the gases to escape.

The crucible is then placed in a wind or blast furnace, and slowly heated so long as fumes escape from it. The heat is then rapidly increased until it reaches white heat, and the furnace is maintained at that high temperature for several hours, the time required depending, of course, on the quantities operated upon.

When it is thought that the operation is completed, the fire is allowed to burn away and the crucible is left to cool. The cover is then removed by means of a chisel introduced in the joint. The crucible is turned upside down and shaken until the slag and metal fall down. The button of metal is detached from its slag with a hammer, and

introduced into well-corked or stoppered vessels perfectly dried.

The slag, which has a fine olive-green color, breaks up in fragments with large faces affecting a pseudo-crystalline structure, but the grain is really crystalline. It is ground, and used as flux in a second smelting. It is advisable after each smelting to add to the slag, in order to make it more fusible, about $\frac{1}{10}$ of the white flux.

The mixing of manganese ore, lamp-black, and flux, is not an indifferent operation, and to insure perfect success it should be done in the following way: The oxide of manganese should be first of all thoroughly mixed with the lamp-black. Then this mixture should be pretty roughly mixed with the flux, and then oil should be added. By so doing, lamp-black and oxide of manganese remain united during the mixing, and act upon each other during the smelting, before the flux begins to melt, so that the oxide is reduced to the metallic state before the flux can dissolve any portion of it. The residue of carbon left by the burnt oil assists in reducing the oxide of manganese, and in preventing the flux from acting upon it before it has been reduced to the metallic state.

It is almost an extraordinary thing that, according to the manner in which substances have been mixed, their chemical reactions should differ; but it must be borne in mind that, in docimastic or metallurgical operations, several successive chemical reactions take place at intervals. Hence the real importance of a systematic mode of mixing.

If manganese ores of a very bad quality were to be used, the slag would, of course, after a few operations, become unfitted for further use; but with good manganese ore, the slag can be used over and over again, and forms an admirable manganese flux.

Very little need be added to these general considerations; the general process will undoubtedly undergo some slight alterations at the hands of those who may be tempted to use it; but the main facts established here must perforce remain the same, the more so that I have been unsuccessful in modifying them seriously. It is extremely doubtful whether any improvements will be made upon the process, chiefly because such improvements could scarcely add to the simplicity of the operation. The only real improvement of importance would be the addition to the flux of a substance which, in small quantities, would assist in obtaining a cast-manganese of a superior quality.

It is worthy of remark that, in presence of either the white or the green flux, charcoal, even in very fine powder, cannot be substituted for lamp-black or for soot. Charcoal powder does not reduce the oxide of manganese to the metallic state, but only to that of protoxide. On the contrary, with the proportions previously given, lamp-black reduces 420 parts of manganese from 1,000 parts of peroxide, or nearly the whole of the metal which it contains.

Is this difference due to the physical condition of both forms of carbon, or to their chemical constitution? Does the non-volatile carburet of hydrogen contained in soot or lamp-black exert a more powerful reducing action than carbon itself? This is very possible, but I have not studied closely this question and am not prepared to answer it.

REFINING OF CAST-MANGANESE.

There is little doubt that, as soon as manganese is prepared on the large scale and at a comparatively low price, some uses will be found for it. I think that, in certain operations, it might form a good substitute for potassium and sodium; and in that case cast-manganese, such as is obtained after the smelting of its ore, could be used with advantage; but, should a purer kind of metal be required for the manufacture of certain special alloys, cast-manganese would have to be refined.

The simplest way of refining manganese is the method which has been proposed by Berthier, I believe, and which consists in re-melting the cast-manganese, coarsely powdered, with about $\frac{1}{8}$ of carbonate of manganese. The mixture is introduced into a refractory clay crucible, and covered over with a wooden cover similar to the one used in the smelting to prevent oxidation.

I need not make any further remarks on so simple an operation.

PROPERTIES OF CAST-MANGANESE: ANALYSES OF THIS METAL AND OF THE ORE.

The properties of cast-manganese, of the refined metal and of pure manganese, are those which are so well known, which have been described so often, and which may be found in any treatise on chemistry. The handling of unlimited quantities of cast-manganese did not bring out any new or remarkable properties worth mentioning. The ore operated upon during the course of

these investigations presented the following composition:

Peroxide of manganese	79.50
Peroxide of iron	6.50
Water	3.50
Phosphate of lime	trace
Gangue	10.50
	100.00

It contains, consequently, 50.5 per cent. of metallic manganese, and 6.5 per cent. of metallic iron.

The cast-manganese obtained from this ore presented the following composition:

Manganese	96.90
Iron	1.05
Aluminium	0.10
Calcium	0.05
Phosphorus	0.05
Sulphur	0.05
Silicium	0.85
Carbon	0.95
	100 00

100 parts of the ore, containing 50 per cent. of manganese, yielded from 42 to 45 per cent. of cast-manganese, containing only 1 per cent. of iron, while the ore itself contains 6.5 per cent of this metal.

Cast-manganese, refined by carbonate of manganese, presented the following composition:—

Manganese	99.910
Iron	0.050
Silicium	0.015
Carbon	0.025
Other substances	traces
	100.000

DOCIMASTIC ASSAYING OF MANGANESE ORES.

Should works be erected for the extraction of manganese on the large scale, the docimastic assaying of manganese ores would undoubtedly offer great interest and be of great consequence. In the course of two hours at most several assays might be made, giving an accurate estimation of the amount of metal which a given ore would produce on the large scale, and enable the metallurgist to judge of the quality of the metal obtained.

The docimastic assay of manganese ore is performed exactly as the corresponding mode of valuation of iron ores, with, however, the modifications required by the new metallurgy. Some white flux and some green flux, prepared exactly as I have described in the metallurgy of manganese, should be kept at hand with the other requisites of the metallurgy of manganese, carbonate of manganese, lamp-black, oil, and a mixture of loam and plumbago.

The experiments should be made on quantities varying from 500 to 1,000 grs. of the ore, and the whole of the operations should be carried out on the small scale exactly as I have described them on the large scale, without any other modification than that of the reduction of the proportions.

I trust that my labors will be lost to neither science nor industry, but that they will be the means of opening a new field of research to the one and of useful appliances to the other.

MODERN PRACTICE OF SHIP-BUILDING.*

From "The Engineer."

Permit me, as a ship-builder, to direct your attention for a little to the past progress and present position of our art, commercial and naval. It is needless, in the time at my disposal, to take you back beyond the last ten years; the interesting transition period in our history, from the building of the first wooden steamer to the building of the last, and the establishment of the iron age in ship-building, is too well known to require special attention here. What has not yet been recorded of it will be written by and by in the popular history of the earlier half of the nineteenth century. What we have to do with now is the fact that iron is established, and the fighting as well as the commercial fleets of the world being reconstructed on principles, proportions, and designs, that would have filled our ancestors of fifty years ago with astonishment, if not dismay; but such things are, and we accept them with the philosophy of people accustomed to sensations, quite prepared to admit that in ship-building and engineering, as in all other departments of modern scientific progress, almost everything under the sun is new.

The merchant ship-building of the last ten years has undergone a great change, not only in style but in construction. The sailing ships, in size and proportion, may

* From an address before the Institution of Engineers and Ship-builders in Scotland, by Mr. ROBERT DUNCAN, President.

be considered steady, if they have not reached their limit. Various causes unite in the ship itself to make a very large sailing ship unprofitable property. The limit may safely be fixed at anything under 2,000 tons. Over that, to any part of the world, a steamer will pay, and, as a matter of course, will take the trade.

The enormous expansion of ocean steam lines since the general adoption of the compound engine is wonderful. The opening of the Suez Canal, as a short cut to India and China, has been an additional stimulus; but it may safely be said that, without the compound engine, steam lines round Cape Horn on the one hand, and direct to China on the other, would have been impracticable. The great desideratum now is, that the coal resources of the world should be properly developed. The risk which the commerce of the world may be said to run from the action of a few wrong-headed miners and speculative coal-masters in Britain, is too serious to be contemplated with satisfaction, and the economical balance can only be safely adjusted by encouraging the development of the mineral resources of all other countries with which we have communication. In India and China superabundant population should make the mining and the mineral cheap. Within the last few years the Chinaman has taken his place in the United States as the most willing and intelligent of laborers, and with a constantly increasing immigration into America of those able-bodied and docile workmen from the far East of the Old World, and Anglo-Saxon, German, and Scandinavian headmen from its far West, a great future is not far distant for the boundless coal and iron resources of America. With India the matter is in our own hands, and with the opening up of South America, China, and Japan by steam, the demand will develop the supplies all in good time.

In our own and other advancing European countries it appears to me that the manual labor of coal and iron getting must be more and more supplemented by machinery. The higher prices paid for labor will compel the adoption of labor-saving implements. Already the agriculture of this country is become more a matter of money and machinery than of men, and the enormous harvest immigrations which we can all remember have given place to the reaping machine, which cuts steadily and never strikes. So it is with the great steamships, which, when produced, do their work steadily and well; but unfortunately the labor necessary for their construction is the least to be depended on of all our elements of production. Year by year the production of machinery is becoming more the product of machinery, the laborer or tradesman being more an attendant than a workman, his skill more of the head than of the hand. It is not so with the iron ship. The furnace and the punching machine may be said to be the two main tools of the ship-builder; nearly all else is labor, fitting depending upon men and not upon machines, while riveting, almost the most important part of the whole, is in the hands of the lowest and least manageable of our workmen. Can the invention of this age and Institution not do something towards the riveting of an iron ship?

With the great expansion in ocean steam trade, and the size of ocean steamers, a great change has taken place in the proportions of the ships themselves, and the arrangements of their scantlings for construction. The earliest ocean steamers of 40 ft. beam and 30 ft. to 35 ft. deep, did not much exceed 200 ft. long; now, the iron ocean steamer of the same breadth and depth exceeds 400 ft. The change has been comparatively gradual, but nearly all in the same direction—length in proportion to breadth and depth. Draught of water being a fixed basis, not exceeding 20 ft. to 25 ft. for the largest merchant ships and principal trading ports, length was the most obvious direction of increase, provided sufficient strength with reasonable weight could be accomplished; and as the *material*, to be efficient, had to be apportioned chiefly to the top and bottom of the ship, large alterations had to be made in its arrangement and distribution, as the ship, to be a profitable carrier on any dimensions, must be a reasonable, and, as nearly as possible, a minimum weight of herself for the weight to be carried. The lead in this rearrangement of scantlings to length and other dimensions was taken by the Liverpool Underwriters' Registry, Lloyd's Registry adhering more to the arrangements for short proportions, which had been in a manner carried forward from the system in practice in the construction of wooden vessels. Eventually the demand for longer and lighter steamers superannuated the older rules of Lloyd's, and within the last three

years the rules of the two Societies have been more nearly assimilated, to meet the growing requirements of the times. The transverse framing in both has been greatly reduced, and the longitudinal proportionately increased, the ratio of weight to tonnage of the largest vessel of the longest proportions being, as yet, very little in excess of the weight by the shortest measure of ten years ago. Possibly a further extension of length might be safely effected, without much increase of weight, by a still further adjustment of the transverse and longitudinal scantlings. I am not of opinion that it would be advisable to reduce much further the vertical side framing by carrying the longitudinal system from keel to gunnel, otherwise we should have the top and bottom buckling together like an accordion. We must have sufficient side framing to give rigidity to the plating, and carry the beams and stringers necessary to the lateral strength of the ship; in the bottom there is reason for believing that longitudinal floors would be preferable in very long ships, and the present system of skin intercostals is an approximation that might be carried further, with advantage to the local and distributed strain on the bottom, at the expense of the material in the transverse floors, but without prejudice to their special functions. The great length exposed the weakness of the top, or upper decks, in long ships to a more marked extent than the bottom; hence the all but universal adoption of iron decks in large ships over nine beams long. But here we approach a limit of length which must be arrived at by stages, according to the work the ship is intended to perform. Weight aloft and high freeboard are incompatible with stability and dead-weight-carrying ability. For a purely cargo ship, the largest displacement and the lowest freeboard, combined with lightness in the ship herself, especially above water, are the essential elements for profit. Therefore the proportions and form which combine the minimum of material in construction, according to the best practical distribution for stability, safety, and speed, with the largest carrying capacity in proportion to cost and economy in working, are the practical limits to the size of our purely cargo steamers. My present impression is that the economic limit of the weight of ships in relation to weight carried, is reached at a length equal to twenty times the draught of water, and thus, if 25 ft. draught be considered the deepest workable limit, with, say, one-third of draught as freeboard, the largest purely cargo ship that it would be advisable to build should not exceed 500 ft. long.

In ships which are intended for combined passenger and cargo trades, height of freeboard is essential to the safety and comfort of the passengers, breadth is necessary to stability with the greater height, and as the dead weight capacity requirement is less in proportion to the gross capacity, by the amount of space or tonnage appropriated to the passengers, the length may be extended in ratio to the extreme depth, without any increase in weight of ships in ratio to gross capacity. To put this in figures, again assuming the minimum freeboard at two-thirds the draught, the extreme depth would be about 42 ft., and the length fully 600 ft. For purely passenger ships, again assuming it possible that the development of ocean travelling should make it desirable that the highest speed attainable could be made profitable between the continents by such expresses of the sea, a midship freeboard equal to the draught would give the required security with 50 ft. extreme depth, and with proportionate strength for a length approximating 750 ft. It would be easy to verify these figures by any of the usual well-known methods of calculating section in ratio to dimensions and weight, assuming the breadth in every instance at not less than one and one-third the extreme depth, or depth three-fourths the beam, as the least desirable for stability with ordinary loading. As no rules are in existence for the scantlings of vessels of such extreme dimensions, and no experience to found on, I am assuming weight in ratio to internal capacity as not exceeding the proportion ruling in the largest under existing rules. But it would be necessary, and probably not difficult, in these large sizes to rearrange the sections so that possibly even greater length might be obtained with the same weight, with safety and advantage. We are carrying out at the present time, since the introduction, or, properly speaking, the general adoption of the compound engine, an economy of the most beneficial character, by the adoption of higher pressure and greater expansion. Pressures of 60 lbs. to 80 lbs. per sq. in. are now common in sea-going steamers, with a consumption of fuel considerably less than half of the ordinary type of marine engine of ten years ago. It is not beyond the bounds of possibility that

we may have safe working pressures of double or treble these figures, as these are certainly double or treble the assumed safest limits of a comparatively recent time, and with corresponding improvement in coal consumption. Economy and profit are the undoubted measures of dimensions in all legitimate trade structures, but whether we shall soon see ships of double or treble their present size may naturally be doubted. We certainly have doubled the length of ships within the last 30 years, and I see no reason to doubt that we may double that again within the next generation. Not quite three years ago, when I designed the new shipbuilding works at Barrow-in-Furness, ships exceeding 400 ft. long were not afloat, with one exception, and when I placed on the plan two ships of 500 ft., receiving their machinery at an 80-ton crane, I thought that I had provided for a considerable future. Since that time you all know that ships above 400 ft. are becoming common, and some approaching 500 ft. are even now in progress on the Clyde and elsewhere. Our 80-ton crane at Barrow is being built to carry 100 tons, and I have been seriously at work upon the plans of ocean steamers 600 ft. long. I cannot say that these ships are to be built immediately, but coming events do not cast very long shadows nowadays, and, looking forward one generation and measuring the future by the past, I think it is not problematical that we shall see steamers of 800 ft. long, the ferry boats of two oceans, with America for their central station, and Europe and Asia for their weekly termini.

Leaving the merchant service to take care of itself, as it is very well able to do, let us look for a little at our navy. Very much greater changes have taken place in it within the last ten years than even in the merchant service. Little more than ten years ago there was not a shell in existence that would pierce an inch plate, and the Warrior and Black Prince were considered impregnable against the heaviest shot then known, behind their 4½ in. of armor plate; but the struggle had fairly begun between guns and armor, or, more properly, between brains and metal, and inch by inch the battle has been fought, and fairly won by the gun. Shells, as well as solid shot, have been driven through the thickest armor plates yet manufactured, and the "first rates" of our navy are now reduced to the Devastation and her sister ships now building, our whole fleet shrinking and sinking before the gun, till in our "mightiest iron-clad" we have a mastless and not very lively turtle, with little more than its back above smooth water.

Thanks to the report of the committee appointed to examine the designs upon which ships of war have recently been constructed, we know rather more about the condition of our naval affairs than we might otherwise have been privileged to learn. That committee was composed of men in many respects well qualified to judge of the merits of those designs, from the evidence before them; among whom it is the honorable distinction of this Institution to have been represented in two of its leading members, Professor Rankine and Mr. Denny, the one of the highest standing on the scientific questions involved, the other equally eminent for practical sagacity on construction. If to these we add Sir William Thomson, Glasgow and the Clyde may fairly claim to have been properly represented. Objection has been taken in some quarters, that the committee have left us no wiser than we were as to the proper design for a modern ship of war, and to the value of their labors and report on the ground that they do not even agree. The first objection appears to me unreasonable on the face of it, from the fact that the deliberations of the committee were expressly restricted, by the terms of their appointment, to the consideration of certain elements in the designs of ships either built or under construction. Beyond that they were forbidden to go, or give an opinion, and it would be manifestly unfair to blame them for not doing what they were expressly prohibited from doing, however capable. On the second point, it appears to me that it would have been astonishing if, under the circumstances, they had agreed, and that it is an evidence, not only of the ability of the committee, but of the general merits of all the designs, that only two gentlemen out of sixteen found it necessary to record a difference of opinion. The witnesses were generally selected for their real or assumed ability to give the best existing information on the points under investigation; and yet, after knowing all that they and the committee can, and cannot, tell us, we cannot help reflecting that the misfortune which led to the appointment of the commission was a blessing in disguise; and as practical men, we know that the result is no disgrace to our naval

constructors, nor to our science and art, whether of ships or guns, nor to our country compared with any other. It is our own guns against our own ships and machinery, and we have the satisfaction of knowing that no other nation has done, or can do, better. Very lately we have been rather alarmingly told Russia, with its model cruisers, its Peter the Great, and its circular iron-clads, is going altogether beyond us; but the steps from the Blonde and the Devastation to either one or the other are not long, and the designs and experience on which they are built are not Russian; they are common to all intelligent men, naval architects, and artillerists. A floating battery that shall offer the smallest mark above water, and carry armor to withstand the heaviest gun that can be sent afloat, is all that is wanted, but not so easily obtained. Fourteen inches is the thickest armor now afloat, and 35-ton guns are also afloat to penetrate it. Our most eminent naval architects assert their readiness to float armor up to 30 in., and our most eminent artillerists are quite prepared as soon as the design is in hand, to make a gun to punch it. Certainly armor can be carried to any thickness, with a very large floating body, and a very small citadel in proportion; but what is to become of the floating body, which cannot be wholly submerged without very great risk? and if at all awash no opponent would waste powder on the armor, when a plunging shot on the easily penetrable hull would end the contest. But supposing the deck were made impenetrable in this way, then comes the torpedo to sink it from below.

The plain fact is that we could not refuse to build such articles so long as France led us, nor can we now, if Russia and Germany choose to spend their money in this fashion; but as our national policy is the reverse of aggressive, it would be folly in us to be first in such a race. We have the satisfaction of knowing without much obscurity the best and the worst that can be done in ships of war; that we have ships equal to the best anywhere else, and are beginning others superior; that we have guns unsurpassed in weight and penetration, and do not mean to stop at that; and beyond that, the experience that has been acquired of the use and power of the torpedo, as an instrument of offence and defence, has demonstrated its value as a coast guard superior to all other modes of coast defence; while its application for the purposes of submarine attack point not indirectly to a revolution, if not to a revulsion, in the practice of naval warfare, and the feelings with which humanity is likely to regard it. Evidently the tendencies of modern warfare on the sea is not to a chivalrous struggle for mastery or honor, but to a murderous intent on wholesale destruction, alike without glory or safety; a contest in which one or both the combatants must certainly perish. The final result of this style of warfare must be that men will refuse to go to sea to certain death, and we shall have a repetition of the game of the Crimean and Franco-Prussian war; the weaker or least prepared will keep in port within a torpedo reef, and the stronger will chafe in idle impotence outside this belt of certain destruction. This brings us to a point which is now assuming prominence, or rather more prominence than it has had the chance of occupying within the last ten years, the question of dispensing entirely with armor, and trusting solely to heavy guns and speed. The position assumed by the advocates of the latter system is not a novel one entirely, having been advocated all through the armor period by those who had faith in the power of attack against the inertia of mere defence. Eleven years ago, in a paper I read to this Association, I maintained that although 1-in. plate was impenetrable by any shell, and 4 in. invulnerable to any shot in existence, it would not continue to be so; that human ingenuity would put shot and shell through the thickest armor that could be floated, and that the last resort, and the only style of ship that would continue to be permanently serviceable, was the flying cruiser with a few powerful guns, and with speed sufficient to choose its own time and distance, and style of attack. Within a year or two of that time the American war developed the low freeboard Monitor and the Alabama, and the naval architects of this and other countries have continued to ring the changes between these two styles ever since. The gun has now, without doubt, asserted its superiority; and the unarmored cruiser of 15 knots speed, with a 35-ton gun fit to send a half ton shot through 18 in. of solid armor plate at half a mile distance, is quite as dangerous an opponent to the Peter the Great or the Devastation with 14 knots speed, and 14-in. armor, as these latter are to her.

Two varieties of these styles have been specially before the public within the last few months, namely, the Russian composite cruiser and the cellular iron-clad, which is in some respects now the favorite in our own country; and you will allow me to draw your attention for a minute to the fact that both of these novelties were very distinctly submitted to this Association in the same vessel by one of our members nearly 8 years ago. Mr. Boolds' composite cruiser, as sketched by him to illustrate his mode of construction, was 320 ft. by 45 ft. by 18 ft. draught, with deep iron frames to main deck, and with a complete iron inner skin joining an iron deck, making a perfect inner ship upon the iron frame, the outside of which was to be planked with wood and coppered. A 6-in. armor belt covered the engine-room amidships. The armament was to be carried in a central cupola, with two large upper deck uncovered guns for bow and stern fire; 500 nominal horse-power, which with the best engines of that time were equal to 800 nominal horse-power of modern compound engines. Twin screws and full masted for sailing. The Russian Grand Admiral is described as 300 ft. by 48 ft. by 23 ft. draught, with an iron inner skin, frames worked outside, planked with wood and coppered. A 6-in. armor belt at the water line. Four upper deck 8-in. guns amidship, protected by an iron-clad barbette, with two 6-in. guns for bow and stern fire. Engines of 900 horse-power and full rigged for sailing. If the coincidence between the two designs be not very natural, it is at least remarkable, but below the main deck Mr. Boolds has further anticipated, by an age at our present rapid rate of transition, the greatest desideratum of the committee on our ships of war, and almost the only point upon which the committee was unanimous, by making a complete cellular ship divided into a greater number of compartments than has ever yet been proposed, except that, by another remarkable coincidence, Admiral Elliott proposes to make his cells exactly the same size. This principle of extensive subdivision below water is being largely adopted by our present naval constructors, and is deemed by other most competent authorities "the most substantial improvement of these times." Mr. Boolds' cells were 12 ft. square from deck to bottom —each cell a water-tight and air-tight bell, with air-pumps and pipes for ventilation, or the expulsion of water in the event of perforation; the theory being the very simple one, that, if the air be not permitted to escape, the water cannot enter; and so long as the deck remains intact, and sufficient pressure is maintained by the air-pumps from the engine, the ship is practically unsinkable, even if a shot were to go in at the water line and out through the bottom. These cells are intended to serve all the purposes of the ship's requirements, as tanks, magazines, and store-rooms, so that no room is practically lost. Going into action, each cell would be hermetically sealed, and a pressure put upon it equivalent to the draught of water, which would be sufficient to keep each and all free under any ordinary penetration; and the crew would, under any circumstances, have the confidence of a provision for their safety as unequalled as it is still unique. Above the main deck Mr. Boolds has another almost equally unique idea of confining the effects of explosive missiles to a limited area, by dividing the ship by thick-plated bulkheads, one over each alternate bulkhead of the cellular transverse divisions below. And as the main iron deck is intended to be as nearly as possible on a level with the water, shot striking immediately above this deck and passing through the other side would have no more effect on the safety of the ship than the port-holes in an ordinary bulwark.

If this naval cruiser, thus roughly indicated to this Institution eight years ago, does not embody the best of the leading ideas as to what a modern ship of war should be, then we are deceived in the most recent expression of opinion of the first scientific men, artillerists, naval officers, and naval architects of this country. Mr. Boolds made a present of his design to the country, but it was too advanced to be worthy of notice until it came back to us in some respects appreciated and appropriated by foreigners.

Circular iron-clads are also the native product of this district. As floating batteries, they are unsurpassable. Mr. Elyder's had some pretensions to a form of least resistance, but otherwise the Russians appear to be most unobjectionable "tubs" Withous assumption, it appears to me that, so far as can be seen at present, we have nothing to fear from the naval developments of Continental Europe, and certainly nothing to anticipate in that direction that a comparatively moderate effort on the part

of our Government and our naval architects, our ship-builders, and our engineers, would not enable us to overtake.

On the motion of Mr. Brownlee, a hearty vote of thanks was awarded to the President for his address.

THE STRENGTH OF FLY-WHEELS.

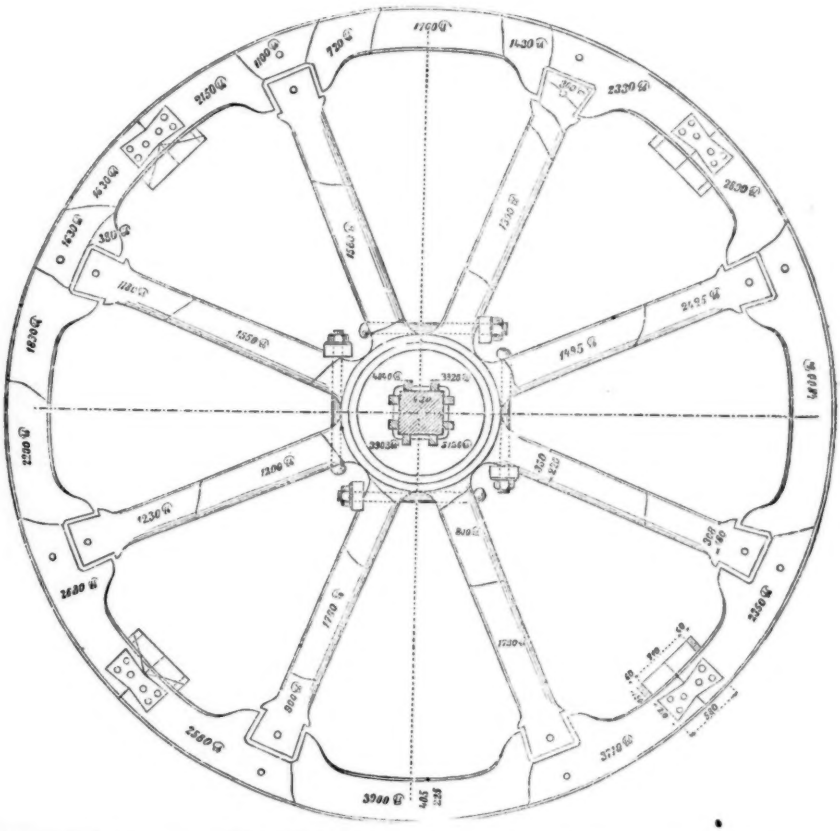
By O. KRUGER.

Abstract translated from "Zeitschrift des Vereins Deutscher Ingenieure."

Not long ago the great fly-wheel of a steam engine in the iron-mill at Burbach (Saarbrücken) was broken.

The diameter was 7.6 *m.*; the velocity at the circumference, 42 *m.*; the weight about 30,000 kilog. Fig. 1 shows the construction and dimensions of the fly-wheel, and the lines of fracture. It broke in many

FIG. 1.



pieces; and one piece, weighing 2,400 kilog., was carried quite a distance. Fortunately no person was injured.

There are in general two causes of the fracture of a fly-wheel. Either the angular velocity is very great or the velocity of the crank suddenly diminishes. In the first case the strains due to centrifugal force

may become so great as to fracture the wheel; in the second case the rim has a tendency to revolve more rapidly, so that the *vis viva* stored up in it puts a strain upon the arms sufficient to break them. The first case may result from a considerable diminution in the resistance of the working machine, from the breaking of cogs, etc., and the second from the sudden resistance of some obstacle to motion. Experience furnishes instances of both kinds.

It appears in the case above mentioned that neither of the causes usually effecting the rupture of fly-wheels can be assigned. The wheel had not long been in use, and no flaws were perceptible; we must therefore seek for an explanation in the construction of the wheel. This shall be done in due time.

In the determination of the strains in the rim due to centrifugal force the effect of the arms is generally neglected. Such a process can give a result only approximately correct.

In his work on Resistance,* Dr. Grashof makes an investigation of strains in which the effect of arms fixed to the rim is taken into account. The results will be applied in this article; in which our object is to modify the complicated general equations given in Grashof's work, so as to obtain rules for special cases, frequently occurring.

The larger fly-wheels usually have 6 to 8 arms. The rim and arms are of cast iron, and the section of the rim is a rectangle. Our investigation concerns fly-wheels of this sort, and we adopt the following notation:

r = radius of fly-wheel.
v = velocity at circumference.
2γ = angle of central lines of adjacent arms; O A & O B (Fig. 2.)
ϕ = the angle D O C.
σ = normal strain at any point of the rim section through D.
η = the distance of the point from the straight line (deflection axis) passing through D, and perpendicular to the plane of the central line of the rim; positive on the convex side and negative on the concave side.
h = the radial dimension of the rim-section.
F = the section of the rim, F_1 = " " arm } both constant.
E = modulus of elasticity.
m = mass of unit of volume.
s = maximum strain in an arm.
P_0 = resultant force and
M_0 = resultant couple of the external force necessary for equilibrium; the rim being divided at C.

*Grashof: Festigkeitslehre.

Fly-wheel with 8 arms.

By substitution in the equations to which reference is made above, we obtain the strain at any point of the rim.

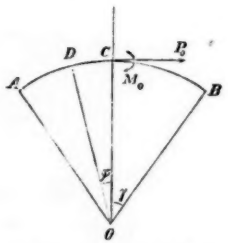
$$\sigma = \left[1 - 0.9745\,a + 12\frac{r^2}{h^2}\left\{\left[\left(1+\frac{1}{12}\frac{h^2}{r^2}\right)\cos\phi - 0.9745\right]a - \frac{1}{12}\frac{h^2}{r^2}\right\}\frac{\eta}{r_0+\eta}\right] m v^2 \quad . \quad (1.)$$

kilograms per square metre. In this value

$$a = \frac{1}{1.46174 + \left(1+\frac{1}{12}\frac{h^2}{r^2}\right)\left(0.00955\frac{r^2}{h^2} + 1.14805\frac{F}{F_1}\right)} \quad (2)$$

From (1) it follows that we must determine the strains produced in the extreme exterior and interior points of the section at A and C (Fig. 2), and consequently those in the sections which lie midway between adjacent arms, as well as those acting in the central line of the arms.

FIG. 2.



To obtain the maximum value of the tension in the rim we need compare only the tensions at the extreme outer and inner points of the section at A and C. Those in C are denoted by σ_1 and σ_2; those in A, by σ_3 and σ_4. Then from (1) we have

$$\sigma_1 = \left[2\frac{r}{h} + a\left(0.0255 - 1.9490\frac{r}{h} + 0.3061\frac{r^2}{h^2}\right)\right]\frac{m v^2}{2\frac{r}{h}+1} \quad (3.)$$

$$\sigma_2 = \left[2\frac{r}{h} - a\left(0.0255 + 1.9490\frac{r}{h} + 0.3061\frac{r^2}{h^2}\right)\right]\frac{m v^2}{2\frac{r}{h}-1} \quad (4.)$$

$$\sigma_3 = \left[2\frac{r}{h} - a\left(0.0506 + 1.9490\frac{r}{h} + 0.6074\frac{r^2}{h^2}\right)\right]\frac{m v^2}{2\frac{r}{h}+1} \quad (5.)$$

$$\sigma_4 = \left[2\frac{r}{h} + a\left(0.0506 - 1.9490\frac{r}{h} + 0.6074\frac{r^2}{h^2}\right)\right]\frac{m v^2}{2\frac{r}{h} - 1} \qquad (6.)$$

Comparison of these four values shows that the maximum strain σ_4 is at the inner points of the section at A, Fig. 2; that is at the inner points of the section whose plane passes through the central line of an arm. Taking 7.2 as the specific gravity of cast iron and putting $m = \frac{8}{109}$ we find

$$\sigma_{max} = \left[2\frac{r}{h} + a\left(0.0506 - 1.9490\frac{r}{h} + 0.6074\frac{r^2}{h^2}\right)\right]\frac{8}{109}\cdot\frac{v^2}{2\frac{r}{h} - 1} \qquad (7.)$$

per square metre, v being expressed in metres.

Regarding the right member of the last equation as the product of two factors, one of which is v^2, and denoting the other factor by β, we write

$$\sigma_{max} = \beta v^2 \qquad (8.)$$

Denote the maximum allowable strain in the ring by k. Then

$$v_{max} = \sqrt{\frac{k}{\beta}} \qquad (9.)$$

v being expressed in metres and k in metre-kilograms.

For the resultant force P_o and the resultant couple M_o,

$$P_o = \frac{8}{109} F v^2 \left(1 + \frac{1}{12}\frac{h^2}{r^2}\right)(1-a) \qquad (10.)$$

in kilograms; F denoting square centimeters; and

$$M_o = \frac{1}{109} F v^2 r \left[0.02551\, a - \frac{1}{12}\frac{h^2}{r^2}(1-a)\right] \qquad (11.)$$

in kilogram centimetres;

To obtain the maximum strain in an arm, let O G, Fig. 3, be the medial line of the arm O E, and O F the bisectors of the angle made by O G with the medial lines of the two adjacent arms, and E F the arc corresponding to the angle E O F. The maximum strain of the arm is caused by the centrifugal force of the portion E F, the resultant of the forces P_0 and the centrifugal force of the arm. The following expressions correspond to those forces:

$$2m\, F\, v^2 \sin\gamma\left(1 + \frac{1}{12}\frac{h^2}{r^2}\right)$$

$$2m\, F\, v^2 \sin\gamma\left(1 + \frac{1}{12}\frac{h^2}{r^2}\right)1-a$$

$$\tfrac{1}{2}\, m\, F_1\, v^2.$$

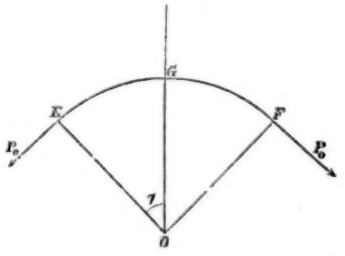
The maximum strain in the arm was

$$s = \frac{8}{109} v^2\left[0.7654\, a\left(1 + \frac{1}{12}\frac{h^2}{r^2}\right)\frac{F}{F_1} + 0.5\right] \qquad (12.)$$

kilograms per square centimetre.

The following tables I. and II. have been calculated in order to facilitate the use of the above equations. Table I. contains the value of $\frac{h^2}{12\,r^2}$ and the values of a obtained by equation (2). Table II. contains the values of β found by equation (8). These values of β, multiplied by the square of the maximum velocity of the periphery of the central line of the rim, give the maximum strain in kilograms per square centimetre.

FIG. 3.



APPLICATION TO THE BROKEN FLY-WHEEL.

In the case of the broken fly-wheel referred to at the beginning of this paper, $\frac{r}{h} = 9.5$; F = 1033, F_1 = 674 sq. centimetres: hence, $\frac{F}{F_1} = \frac{1}{2}$; and the maximum velocity at the circumference was 42 metres.

For $\frac{r}{h} = 9.5$ and $\frac{F}{F_1} = 1.5$. Table II. gives $\beta = 0.1141$. By equation (8).

$\sigma_{max} = 0.1141 \times 42^2 = 202$ kilog. per square centimetre. Assuming the coefficient of absolute resistance of cast-iron at 1250 kilog. per square centimetre, the rim, considered as of one piece, has six-fold security.

To determine the maximum strain due to centrifugal force in an area we employ equation 12. From Table I.

$$\frac{1}{12}\frac{h_2}{r^2} = \frac{1}{1083};$$

$a = 0.249$. By substitution

$$s = \frac{8}{109}.42^2\left[0.7654.\frac{1084}{1083}.0.2470.1.5 + 0.5\right]$$

$= 102$ kilog. per sq. centimetre. The arms have twelve-fold safety.

TABLE I.

	$\frac{1}{12}\frac{h^2}{r^2}$	$\frac{F}{F_1}=4$	$=3,5$	$=3$	$=2,5$	$=2$	$=1,5$	$=1$
$\frac{r}{h}=5$	$\frac{1}{300}$	0,1585	0,1741	0,1939	0,2183	0,2497	0,2916	0,3505
$=5,5$	$\frac{1}{363}$	0,1573	0,1730	0,1921	0,2160	0,2467	0,2875	0,3445
$=6$	$\frac{1}{432}$	0,1560	0,1714	0,1902	0,2135	0,2435	0,2831	0,3383
$=6,5$	$\frac{1}{507}$	0,1546	0,1697	0,1881	0,2109	0,2400	0,2784	0,3315
$=7$	$\frac{1}{588}$	0,1531	0,1679	0,1859	0,2081	0,2364	0,2736	0,3246
$=7,5$	$\frac{1}{675}$	0,1516	0,1660	0,1835	0,2052	0,2326	0,2685	0,3175
$=8$	$\frac{1}{768}$	0,1499	0,1640	0,1811	0,2021	0,2287	0,2633	0,3103
$=8,5$	$\frac{1}{867}$	0,1482	0,1619	0,1786	0,1990	0,2247	0,2580	0,3029
$=9$	$\frac{1}{972}$	0,1464	0,1598	0,1759	0,1957	0,2205	0,2525	0,2954
$=9,5$	$\frac{1}{1083}$	0,1445	0,1576	0,1733	0,1924	0,2163	0,2470	0,2879
$=10$	$\frac{1}{1200}$	0,1426	0,1553	0,1705	0,1890	0,2121	0,2415	0,2804

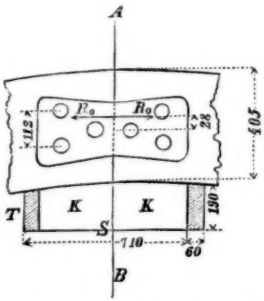
TABLE II.

	$\frac{F}{F_1}=4$	$=3,5$	$=3$	$=2,5$	$=2$	$=1,5$	$=1$
$\frac{r}{h}=5$	0,0887	0,0894	0,0902	0,0913	0,0927	0,0946	0,0972
$=5,5$	0,0896	0,0905	0,0916	0,0930	0,0947	0,0970	0,1002
$=6$	0,0907	0,0918	0,0931	0,0946	0,0967	0,0994	0,1031
$=6,5$	0,0919	0,0931	0,0945	0,0963	0,0987	0,1017	0,1060
$=7$	0,0930	0,0944	0,0960	0,0981	0,1006	0,1040	0,1087
$=7,5$	0,0942	0,0957	0,0975	0,0997	0,1025	0,1062	0,1113
$=8$	0,0954	0,0970	0,0990	0,1014	0,1044	0,1084	0,1137
$=8,5$	0,0966	0,0983	0,1004	0,1030	0,1062	0,1104	0,1160
$=9$	0,0978	0,0996	0,1018	0,1045	0,1079	0,1123	0,1182
$=9,5$	0,0989	0,1008	0,1032	0,1060	0,1095	0,1141	0,1202
$=10$	0,1000	0,1020	0,1045	0,1074	0,1111	0,1158	0,1220

Considering the fact that neither of the causes producing rupture could be assigned in the above-mentioned case, and that there were no flaws in the iron, we infer that the cause of rupture must be sought in the manner of binding together the parts of the rim.

The rim consisted of four equal portions, connected by fish-plates L, L, Fig. 4, which were fastened by three cast-iron rivets. There were besides, shoulders (K K), with a wrought-iron ring T welded around them.

FIG. 4.



Suppose the connected parts cut by a section A B; and that equilibrium is due to a resultant force P_o, and a resultant couple M_o. Then, from equation (10).

$$P_o = \frac{8}{105}.\ 1033.42^2\left(1+\frac{1}{1083}\right)(1-0.2470) = 100800 \text{ kilog.}$$

P_o and M_o unite in a resultant force $R_o = 100800$ kilog. The distance of the point of application from the centre of gravity of the section (K not considered) is found by dividing M_o by P_o; it lies between this centre of gravity and the external cylindrical surface of the rim of the wheel. From (10) and (11) we have

$$\frac{M_o}{P_o} = \frac{380\ (0.2551.\ 0.2470 - \frac{1}{1083}\ 0,7530}{\left(1+\frac{1}{1083}\right)0,7530} = 2.8 \text{ centim.}$$

It is is possible that at first the ring T alone acted. Assuming this to be the fact, suppose the forces R_o to act in opposite directions on both parts of the rim, then an effort of rotation is produced about a straight line through S parallel to the axis; and the force acting on the ring T, with dimensions in millimetres, as shown in Fig. 3, is

$$\frac{100800 \times 420}{95} = 245700 \text{ kilog.}$$

This force is distributed upon two sections of 114 square centim., giving 1955 kilog. to the square centimetre. Taking 4000 kilog. as the modulus of resistance of wrought iron, and 1400 kilog. as the proof strength, it is obvious that the ring possessed only twofold security, and that the limit of elasticity was passed. And it is to be observed that the welding of the ring had caused a certain tension, thus reducing the strength of resistance.

After the rupture of the ring the plate-binding came into action. Supposing the plate (for each rivet) a perfectly rigid body, and that the strains on the three rivets occurred at the same time, then the force upon the rivet most strained would be more than $\frac{100800}{2} = 50400$ kilogs. The rivets were cast-iron, 4 centim. large. They were subjected to a shearing strain. If a force of $\frac{50400}{2}$ kilog. acts upon a section of 12.566 square centimetres, then the strain per centimetre is $\frac{25200}{12.566} = 2006$ kilog. Assuming the modulus of shearing resistance of cast-steel at 7500 kilog. per square centimetre, a force of 2006 kilog. would correspond to three and four-fold safety. The actual result did not show so favorably.

The cause of rupture may be referred with some probability of correctness to the manner of junction of the two parts of the rim. At the point marked A the ring was torn, the rivets were sheared, and the shoulders K K were broken off. This last circumstance is explained in this way. After disconnection due to centrifugal force, the two parts of the ring tended to move outward, causing a rupture at the nearest points (B, C) that resisted this tendency. The shoulders K K must hence exercise a considerable pressure one upon the other.

If a rim consists of parts they should be so connected that they may be regarded as forming a single piece. And it is to be remarked that the strains in a section are not uniform, and in the section midway between the two arms, as appears in (3), (4), (15), and (16), the external strains are greater than the internal. In the case of the fly-wheel under consideration we derive from (3) and (4) $\sigma_1 = 138$ kilog., $\sigma_2 = 55$ kilog.

In the iron works of Gebr. Stumm, at Neunkirchen, fly-wheels are made of entire cast-iron rings. For instance, one fly-wheel consists of three rings of equal exterior and

interior diameters. It is certain that such a construction has its advantages. But generally it is not possible to cast rings of sufficient size.

From equations (7), (19), with (2) and (14), it follows that the maximum strain in the rim is independent of the magnitudes $\frac{r}{h}$, $\frac{F}{F_1}$ and v. For determined values of $\frac{r}{h}$ and $\frac{F}{F_1}$ it is proportional to the square of v. The influence of the ratio $\frac{r}{h}$ is shown in Table II. The maximum strain increases with $\frac{r}{h}$. For a fixed value of r it increases as h decreases. This should be remembered in the construction of fly-wheels.

The equations and tables show that the maximum strain decreases as $\frac{F}{F_1}$ increases. If this alone were regarded, the section of the arm should be as small as possible.

From equations (12) and (14) it follows that the maximum strain in the arm, as of the ring, depends upon $\frac{r}{h}$, $\frac{F}{F_1}$ and v, and for fixed values of $\frac{r}{h}$ and $\frac{F}{F_1}$ is proportional to the square of v. It increases with $\frac{r}{h}$ and $\frac{F}{F_1}$. This is due to the action of the ring upon the arm. If the arms are not rigidly fastened to the ring, so that they serve only to transmit the motion from the axis (the centrifugal force of the ring not affecting the arms), the maximum strain for either arm or ring is less.

For ordinary values of $\frac{r}{h}$ and $\frac{F}{F_1}$ the maximum strain in the rim is far greater than that in the arm. Making the values of σ_{max} and s equal, it is seen that the quotient $\frac{F}{F_1}$ is generally large, if both maximum strains are equal, provided that the centrifugal force only is acting.

The arms should be made capable of great resistance, in view of the fact that a great strain may be produced in them by any suddenly interposed obstacle. This should be especially remembered in cases in which sudden shocks are common, as in rolling-mills and trip-hammer shops.

THE NORTH SEA CANAL OF HOLLAND, AND THE IMPROVEMENT OF NAVIGATION FROM ROTTERDAM TO THE SEA.*

A description of these two great works by one of our most prominent American engineers is a valuable addition to current scientific literature. The great importance of these artificial waterways, the magnitude of the operations, the theories of wave, current and tidal action necessarily taken into account in all the plans of construction, all render this report peculiarly acceptable to members of the profession on this side of the Atlantic, where, although these problems are not yet presented for solution on so large a scale, it seems certain that the exigencies of rapid growth of our country will demand such work even of our present generation. The ripe experience and the thorough and varied culture of the writer of this report has insured its completeness as a professional document. We extract such portion of the book as shall afford the theory and plan of the operations, omitting such description of details as require the plates to describe properly.

THE NORTH SEA CANAL.

Nearly all of Holland is alluvion, like the delta of the Mississippi and Nile, sedimentary deposits of the rivers which have thus raised the regions in the vicinity of their outlets to nearly the ocean level, and created what might be called a debatable ground between land and sea, such as we may now observe still unreclaimed in the extensive areas of swamp and marsh which constitute the delta of our own great river. Along the sea margin of this region in Holland nature has erected a barrier in the almost continuous "duins" or downs—hillocks of sand thrown up by the waves and drifted inward with the winds. This barrier has a width sometimes exceeding a couple of miles, and rises to a height of 40 or 50 ft.

* Report on the North Sea Canal and on the improvement of navigation from Rotterdam to the Sea, to the Chief of Engineers U. S. Army, by Brevet Maj.-Gen. J. G. BARNARD, Col. Corps of Engineers, U. S. A. Washington: Government Printing Office. For sale by Van Nostrand.

The margins of the streams receiving the most copious sedimentary deposits, and hence more elevated than remoter areas, present not unfrequently the only firm ground of a region otherwise naught but marsh, and form natural dikes against the overflow of their own waters or those of the ocean tides. Thus, too, it happens that far the greater portion of the land is excluded from direct drainage into river or ocean below the higher levels of which it is situated, and can only throw off its surface waters into the ocean by communications of its own through the sand barriers, through which, in return, it is subject to daily overflows by the tides of the ocean, or, if above their level, to casual inundations by storm tides. The inland basin of the Zuyder Zee is, hence, the natural drainage basin for the greater part of Holland, and it is through this estuary, now united to the North Sea by deep and permanent channels, that Holland is exposed to, and has experienced, the most formidable irruptions of the ocean waves.

From the southeastern extremity of the Zuyder Zee, an arm, known as the Y (Heb Ij), protrudes, with an easterly direction towards the sea-coast, distant about 20 miles. It reaches almost to the very foot or landward slope of the downs, terminating in what is called the "Wijkermeer," from the margin of which to the sea-coast through "Holland op zijn Smalst (*i. e.*, the narrowest part of Holland), the distance is less than four English miles.

Amsterdam, situated on this arm, is about four miles from its debouche into the Zuyder Zee.

The depth to the quays of the city, and for a short distance beyond, is considerable. Near the debouche, and in the contiguous portion of the Zuyder Zee, is the "Pampus" bar, one of the most serious obstructions to the navigation. To the westward of Amsterdam the Y expands to a width of three or four miles, while its depth shrinks to two metres. In the Wijkermeer the depth is probably still less.

The superficial strata, through which the canal is made, consists, as in all alluvial regions, of mud, clay, and sand in various proportions. The bottom of the Y, where shoal, is covered with mud, beneath which are layers of clay and sand, very much as along the margins of the Mississippi. The sand-hills ("duins"), which constitute the sea-margin, are, of course, sea-sand, extending to depths reached by trial borings. The motives which have prompted the undertaking of this great work are set forth in what precedes. It only remains to furnish some few matters of information which are not given in the very full description of the resident engineer, from which I have quoted.

One of the most important features in the actual project is the entire isolation of the canal from the Zuyder Zee, by means of the great embankment or dam across the Y, from Schellingwoude to Paardenhoek. Not, indeed, until the public mind became reconciled to this feature (hostility to which had already, at an earlier date, interrupted one great enterprise for ameliorating the navigable communication of Amsterdam with the sea) could, as fully set forth by Mr. Dirks, an entirely satisfactory project for a direct communication with the ocean be devised.

To leave the canal open to the fluctuating levels of the Zuyder Zee; to interfere, by its construction, with the drainage system of the rich regions bordering the Y, while exposing them to dangers from which they were before exempt, involved so much that was objectionable—militated against so many interests—that projects otherwise so meritorious as to receive the sanction of various commissions of engineers and scientific men, failed, as we have seen, for years, to secure legislative sanction.

The execution of this dam across a tidal channel of several metres in depth, involving the construction, in the midst, of a system of locks so ample that the barrier should not even be felt as an obstruction to the teeming navigation from the Zuyder Zee; and of drainage, sluices, and machinery adequate to discharge all the rain-fall and surface water of the Y itself, and of the extensive "polders" which border it, is one of the most important and remarkable features of the enterprise.

The distance from shore to shore is 1,480 metres, of which, the locks occupying 120 metres, 1,360 constitute the total length of the dike. Of this length 300 metres connect the north shore with the locks, the remaining 1,060 metres extend from the locks to the south shore at Paardenhoek. The locks were built in 3 metres of water, and in the gap, still open, there is said to be 5 and even 8 metres, and the mean depth is 2½ metres.

The bottom swept over by the current of

the Y, was probably not muddy, in the deeper portions at least, but, to the depths reached by the piling for the locks or by borings, sand and clay in various proportions and stratifications. The ordinary tidal fluctuation is, here, about 1 ft. (0m.30), but storm tides sometimes reach the height of 1.50 metres above A. P.*

The dike is commenced by sinking to the bottom mattresses of fascine work, weighted with ballast stone and long enough to stretch across the full width of the base. Revetements of fascine work in narrower mattresses, sunk one above the other, are carried up along each margin to the level of A. P., between which clay and sand constitute the mass of the dike.

A thickness of at least 1 metre of clay covers the embankment, the slopes of which are temporarily revetted by osier work and ballast stone; to be replaced ultimately by a permanent stone pavement.

The puddling between the concentric rows of piles was of clay brought from the vicinity of Amsterdam. Wherever iron bolts passed under water from one ring to the other, through the puddling, they were found to cause leaks, and their removal was necessary. The exhausting of the water from the interior of the dam was effected in four days by a small portable engine of 10 or 12 horse power. The excavation for the lock foundations was carried beyond 5.50 metres below A. P., the piles being capped at this level. The weight-bearing capacity of each pile was carefully estimated, and the piles classified according to their several capacities. In the highest class are those which penetrated, *e. g.*, 11 centimetres under the last ten blows of the hammer, of 800 kilograms weight, falling 4 metres. In the lowest class, *e. g.*, 77 centimetres (about) is the final yielding of the pile under the blows.

Of course, the different classes are indiscriminately mixed, the intention being to get the bearing capacity as nearly uniform as possible. To this end test piles were driven in different places to determine the lengths required to furnish the desired resistance. Wherever insufficient resistance was found, *i. e.*, wherever the penetration of these test piles exceeded 5 centimetres for the final volley of thirty blows of a ram of 800 kilogrammes falling 1.50 metres, the defect was remedied by increasing the number of piles.

For the ordinary driving the fall of this ram was 4 metres (13 ft. 2½ in.); the resistance or weight-bearing capacity in kilogrammes was estimated by the simple and obvious formula:

$$R = \frac{B\,H}{6\,e} \cdot \frac{B}{B + P}$$

in which—

R = sustaining power of the pile.
H = height of fall of ram.
B = weight of ram.
P = weight of pile.
e = penetration effected by the last blow, the numeral 6, by which it is multiplied, being the coefficient of safety. H and *e* must be measured by the same unit, whether it be metres, feet, or inches. The resistance, R, will be expressed in the same weight-unit in which B and P are measured.

The weight of the iron chambers is so nearly balanced by air-chambers as to relieve the hinges from strain and to render rollers unnecessary. All the gates are worked by chains and capstans, the use of thrust-bars being precluded by the narrow walls which bound the parallel lock-chambers.

The canal excavation through the downs from the North Sea locks to Velsen is to the depth of 5 metres below A. P. done by hand, the material being thrown into rail cars, by which it is transported either to the contiguous margins or to wharves at Velsen to go into the dikes which extend through the waters of the Y.

When the water is let in, the remaining depth of 2.50 metres will be excavated by dredging. To make the dikes bordering the canal through the waters of the Wijkermeer and Y, sand from the excavation through the downs is brought to the wharves at Velsen, loaded on scows which are towed to the point where needed. The dikes are raised with this material from the natural bottom up to 0m.50 below A. P.; ½ metre below the present mean level of the Y. These dikes leave a wide berme (30 metres) between them and the canal excavation.

This excavation now commenced by dredging-machines, the material being deposited upon the already made sand nucleus of the dikes. These wide bermes are intended mainly to protect the dike-slopes against the wash of the canal waves. A temporary

* A. P., Amsterdam Peil ("Peil" signifying "gauge" or "sounding.") The fixed plane of reference for all surface or water levels in Holland, and even in contiguous territories.—J. G. B.

revetement of fascine or ozier works protects these dikes till the water surface between them shall be brought to its proper level and the external waters drained. Through the sand-downs and outside of the sea-locks the sides of the canal will be revetted with stone for one metre above the water level.

One of the important and characteristic features of the project is the drainage of Wijkermeer and the Western Y. All the area covered by these waters, not included between the dikes of the main canal or those of its branches, will be drained and converted into habitable and arable land. This area amounts to 5,000 hectares (12,500 acres, nearly). For this drainage, steam machines (Appold's centrifugal pumps) will be erected at suitable points to lift the waters of the new-formed "polders" into the canal. Moreover, the canal becomes necessarily the recipient of the drainage of the extensive polders now bordering the Y, and it is a stipulation deemed, I believe, somewhat unnecessarily stringent, that the Company shall maintain the level of the canal, including, of course, the open waters of the Y, within the Schellingwoude dam, at the level of 0m.50 below the present mean Amsterdam level (A. P.)

Some considerable portion of this drainage can be effected through the North Sea locks at low tide—for the mean range of the sea-tide is from minus 0m.50 to plus 1 metre—but even in ordinary weather the period of outflow will be too short, and under the influence of the winds, weeks, during which the gates cannot be thrown open, may elapse.

Hence the main reliance for draining the canal basin, is the powerful draining machinery consisting of three Appold centrifugal pumps, as already mentioned, connected with the Orange locks. They are estimated to be capable of discharging 2,000 cubic metres (74,000 cubic feet) of water per minute; or of raising that quantity 0m.50, that being the average lift from the level of the canal to that of the outside water of the Zuyder Zee.

The entire work of execution of the great enterprise, now far advanced toward completion, is performed under single contract with the firm of Henry Lee & Sons, of London, whose capacity has been before proved through the successful construction of several of the great public works of England.

IMPROVEMENT OF NAVIGATION FROM ROTTERDAM TO THE SEA.

The existing routes taken by sea-going vessels in reaching or leaving Rotterdam, are as follows:

I. The shortest and most natural route is to follow the Nieuwe Maas, by Maassluis or Brielle, between the Hook of Holland and the island of Voorne.

II. By the Nieuwe and Oude Maas, Dordrecht Kil, etc., vessels descend the Nieuwe Maas as far as Vlaardingen, ascend the Oude Maas, and pass through the Dordrecht Kil into the Holland Diep. After passing through the Holland Diep this channel (or route) divides into two, one following the "Haringvliet" and outlet of Goeree (Goeresche Zeegat); the other through the flats of Ooltgensplaat, the Volvak, the Krammer, the Grevelingen, and through the Brouwershaven Pass to the sea.

III. From Rotterdam through the "Noord" by Dordrecht to the Goeree Pass, principally used by vessels of small draught, there being many shoals, especially in the Noord.

IV. From Rotterdam down the Nieuwe Maas to Vlaardingen, thence by the Oude Maas, the Spui, and Goeree Pass. But slightly more practicable than the preceding, on account of shoals in the lower part of the Spui, used occasionally by light-draught vessels, especially steamers.

Owing to the unsatisfactory character of these four (or rather five) routes of navigation, beset with shoals, leading sometimes up and sometimes down stream, the canal of Voorne was constructed in 1827—29, and has been since in continual use.

Various projects have been made since the execution of the Voorne Canal for obviating the defects attending the navigation of that route. One of these, by a former Chief Engineer of the Waterstaat, Greve, consists in the construction of a jettee, starting from the island of Voorne toward the shoal of the Hindee, thence making an elbow, running parallel to the Goeree shore, and terminating in the sea at the line of 5 metres below low water, or 7 metres below ordinary high water. This jettee—nearly nine miles long—would have cost 7,500,000 florins.

It was also proposed by Mr. Greve, and Mr. Conrad (an engineer of the Waterstaat), to construct a new canal through Goedereede connecting the Haringvliet with the Springersdiep, and thence leading to the

Brouwershaven Pass. In connection with these projects, it was proposed to increase the length of the locks of the Voorne Canal, and also to make various improvements in the river navigation, by closing of unused channels, or by jettees or natural dikes.

Another project made by Chief Engineer Greve, in 1857, by order of the Government, was to improve the entrance to the Nieuwe Maas by the construction of two dikes of fascine work, the northern one starting from the Hook of Holland, in a southwesterly direction, gradually curving to westerly and extending to the depth of 5m. 50 below ordinary low water. The southern one to start from the island of Voorne and approaching the first to run parallel with, and at a distance from it of 750 metres, till it reached the depth of 5 metres.

A plan for the same object and very similar in character, but much less expensive—the piers being lower and shorter—was made about the same time by the Engineer of the Waterstaat, Caland. A year or two (1858), the same Engineer presented to the Waterstaat a plan differing from the two just described, in these important particulars: that the northern arm of the Nieuwe Maas, the "Scheur," is followed, and instead of attempting to obtain an outlet through the old mouth and over the old bar, a cut is proposed through the Hook of Holland, directly to the sea. The plan also contemplates the improvement of the whole river, from Krimpen to the sea, by means of lateral dikes for modifying the direction of the currents and correcting the immoderate channel widths, and by augmenting the same when too contracted. * *

The second plan of the Engineer, Caland, was adopted with but slight modifications by the Commission, and is now far advanced in successful execution. In connection with its adoption of this project, the Commission presents, as applicable to it and to the general subject of the improvement of the navigation into the mouths of tidal rivers, the following "general considerations:"

"Theory and experience have taught, and the documentary information forwarded to the Commission, as well as the observations of our fellow-member, Caland, upon our tidal outlets, confirm their testimony, that the most influential agent in maintaining the depth of our navigable channels is to be found in the *velocity* with which the water moves through the channel section. When velocity and volume of water are insufficient with regard to the profile, a constant regimen cannot exist.

"If these cannot be increased sufficiently to maintain a profile adequate to the needs of commerce, the ends can only be attained by dredging or by a resort to artificial canals.

"The incessant action of tides and waves maintains in constant motion the sands and rocky fragments along our coasts, establishing a bottom slope of from 250 to 140 base to rise, between the Hook of Holland and the Helder, so that no nearer than 800 to 1,300 metres from low-water line can a depth of 5m.50 be found; or for 7 metres below high water, the depth needed for large vessels.

"The drainage water which flows down our rivers is, owing to the immoderately great profiles of the mouths, quite inadequate to maintain, through this slope of the shore, a channel of sufficient depth for the passage of large vessels; but the tide enters the mouths, and, during the ebb, is discharged along with the accumulated drainage water, of which, however, its volume is many times greater. Hence it is comprehensible that it is to the action of the tides mainly that the maintenance of depth in our river mouths must be attributed.

"The total effect depends upon the velocity and volume; both increase with the tide range, that is, with the difference below high and low water. Hence it is found that the entrances of our rivers increase in depth in going southward.

"It is not in the power of man to increase the tidal range, but the direction and form of the entrance may be regulated and the breadth limited to due proportion to the volume, and thus the depth may be increased.

"The outlets of our rivers in the North Sea have all (some more, some less) a curve to the southward, whereby they better intercept the tidal current flowing from out the channel.

"The shortest line to reach the required depth is directed northwestward, because the coast line lies northwest; but as the tide stream comes from the southwest, the direction of the entrance should lie, at least, east and west.

"Rivers do not discharge the same volume through every profile, but the nearer the sea the greater the volume. Hence, to

maintain an equal depth, the width must be the greatest at the outlet, diminishing funnel-wise in ascending.

"*Lateral Dikes.*—Externally, it is out of the question to employ anything else than such dikes and piers. Such have for a long time existed at the two entrances to the Gueldrian Issel, the Ketel, the Ganzediep, and at the entrance to Zwartewater in the Zwolsdiep.

"Inland it is more common to limit the breadth of rivers by jettees of crib-work (*dwars-kribben*), and we are far from condemning this, frequently less expensive, method; but we consider it undesirable for the lower rivers, since between the cribs there remain basins (or areas) which the tide must fill to the prejudice of its upward flow. The farther up the tide can be enticed, the more powerful will be the downward flow of the ebb; hence, in our plan, we give the preference to lateral dikes."

The facts and reasons thus set forth in the report of the Council involve much that is of great interest to engineers. While on the one hand there is shown the greatest caution in attempting to alter existing channels, and reliance is had rather upon bringing natural forces to bear than applying artificial ones, yet, on the other hand, the bold step is taken of closing an existing mouth and creating another for one of the great outlets of the combined Rhine and Meuse, and of projecting into the sea, upon a sand shore, entrance gutters reaching to 4½ fathoms (low water) line.

In this respect the projects seem even bolder than that of the artificial harbor for the North Sea Canal. These jettees differ from those of the last-named harbor in this important particular: they are of fascine work, and they are, moreover, the *first* constructions of that kind ever attempted upon the open sea shore.

Universal as is this kind of hydraulic construction for the dams and dikes obstructing or confining internal waters, no attempt has been made to project a jettee into the sea in this way. The construction of those of the North Sea Canal Harbor has demonstrated triumphantly that artificial jettee construction, with concrete blocks, regularly laid, is practicable even upon a sand shore; but the experience by which the knowledge is gained was acquired through frequent failures and much loss of time and money. The history of the jettee construction at the Hook of Holland has been one of complete success. No disaster has occurred, and the completed structure seems to bear the severest storms, the most violent wave-force, undisturbed. The interstices of the fascine work, as well as those of the stones with which the successive layers are ballasted, become very speedily densely packed with sand, which probably extends itself likewise into the spaces between the stones subsequently thrown down as a revetement to the sides and base bermes. This sand-filling together with the piles, which are driven in the margins and slopes, must be referred to, I presume, to account for the fact that even at the pier-heads the revetting stone (of no great dimensions, as has been seen) are not seriously disturbed by wave-force. To the filling of sand also is due the preservation of the fascine work from the attack of the worm. The piles, where thus exposed, are covered with worm-nails. All sawed woodwork is coated with tar, and the iron-work is painted while warm, twice with red lead, and again with black paint.

The two jettees being completed at the time of my visit, so far at least as the laying of the "*zink-stukken*" is concerned, I was not fortunate enough to witness the process; but the details which I have given from Dutch authorities concerning this matter of construction, together with the description of the jettees, have sufficed, probably, to make intelligible the process of construction of these jettees.

The total width of the Scheur where dammed, measured at water surface, was between 300 and 400 metres. This outlet could not, of course, be stopped until a new channel should be cut through the Hook of Holland. While the latter work was in execution, "cribs" (*kribben*) or jettees, connecting with the shore embankments, were projected from either side, contracting the channel to 130 metres, and confining it to the deepest existing portion.

Lest the accelerated tidal currents should abrade the bottom of this opening, a "*bezinking*" (or bottom revetement of fascine work, with the usual-stone ballasting) was sunk, extending from crib to crib.

In process of time it was found that the bottom along and contiguous to the edges of this was greatly deepened, and undermining the edges.

The difficulty of the subsequent construction of the dam was thereby greatly enhanced, since the regular process of sinking

of mattresses could not be applied until the great inequalities of the bottom were levelled by, as I suppose, the application, along the edges and in the deeper portions, of successive small pieces. The dam was completed at the time of my visit.

The general method of construction has been already given, and applies equally to the harbor jettees—the great dam at Schellingwoude and the dam in question.

To the new outlet is to be given, as has been already stated, a width of 800 metres, increasing at the origin of the entrance jettees to 850, and at their outer extremities to 900 metres. The old outlet of the Scheur had about 350 metres width at its surface line, probably not over half that width of deep-water channel. Hence the augmented width of the new entrance implies a greatly increased in and out flow of tidal water. At the time of my visit, early in October, 1871, the channel had been cut through to a width of about 200 metres, and quite recently opened. It was intended to enlarge it gradually to the full projected width. Between the harbor-piers a narrow, somewhat crooked, and not yet navigable channel had formed. By letter of the 30th of March, the Chief Engineer, Mr. P. Caland, informs me that "steam and sailing vessels are actually passing through the new water-way of Rotterdam to the sea, and to all the parts of Europe."

The work is regarded as a complete success. In conclusion, I remark that Rotterdam, like Amsterdam, has found her existing communications with the sea insufficient for the demands of her commerce—inadequate to the exigencies of the modern instruments of ocean navigation. Both cities, aided by their Government, have had recourse to extraordinary means of regaining their rank among the great sea-ports of the world. While the principles involved in the very dissimilar projects to which they have had recourse—each shaped and governed by respective local circumstances—are not without applicability to our works of river and harbor improvement, and are certainly of great interest to engineers, it is believed that the peculiar methods of hydraulic engineering of Holland, which have found a novel and heretofore untried application in the forming of a new water-way from Rotterdam to the sea, may be found extremely useful in our own country. In the construction of harbor jettees, or even breakwaters, upon our extensive sand coasts, the system deserves the trial. While, intrinsically, much more economical than constructions wholly of stone, it is to be observed that, generally, the localities where it is applicable are destitute of that material, while they abound in the necessary materials for fascine-work. In its application to inland waters, it seems to me likely to prove especially available in Louisiana. For the damming of deep river arms and the construction of dikes, its efficiency has been proved by the experience of centuries in Holland.

REMARKS ON THE THEORY OF AIR AND STEAM ENGINES.

By W. J. MACQUORN RANKINE, C.E., LLD., F.R.S.

From "The Engineer."

It is well known that the injection of a certain small quantity of air amongst the steam that is to supply a steam engine has been found to produce improved economy of heat to a certain extent. There are obvious causes for this fact connected with the more efficient communication of heat from the fuel to the water and steam. For example, the air may be previously passed through tubes which expose a large surface to the fire in addition to that which the steam boiler alone presents, or the air may be itself part of the products of combustion, being freed from dust by suitable processes.

The following remarks are intended to show that according to the principles of thermodynamics the air has a tendency, independently of the communication of heat from the fuel, to increase the efficiency of the steam in transforming heat into motive energy, and to show that it is worth while to test how far this beneficial action can be carried in practice, by the aid of experiments in which a larger proportion of air shall be employed than has hitherto been tried. It is well known that the efficiency of any heat engine is limited by the temperatures between which it works; the greatest possible

efficiency, that is, ratio of work done to heat expended between given limits of temperature, being expressed by dividing the range of temperature by the absolute temperature at the higher limit.

In order that this theoretical duty may be realized, it is essential that all heat whatsoever received by the working substance should be received at the highest limit of temperature, and all heat rejected by the same substance given out at the lowest limit. Any deviation from these rules gives rise to an expenditure of part of the heat without producing the full quantity of work due to the assigned limits of temperature. It is obvious, therefore, that in order to approximate to the theoretical limit of performance already mentioned, the changes of temperature in the working substance ought, as far as possible, to be produced mechanically—the rise by compression, the fall by expansion. One of the best known deviations from the before mentioned rules occurs in the case of the feed-water of a steam engine. In ordinary instances the water is raised from the temperature at which it is obtained to that at which it is to be evaporated by the expenditure of fuel and not by mechanical means; the consequence of which is that this heat fails to produce the quantity of work which it would produce were the same quantity of heat communicated to the water, or to the steam from that water, at the higher limit of temperature.

When air alone is made to act in this manner, it works as in the engine described as Joule's in my book on "Prime Movers." The efficiency depends on the temperatures at which the heat is respectively received and rejected by the air, and the proportion borne to each other by those temperatures depends on the absolute pressures at which the air is heated and cooled respectively; for example, if the air is heated at five atmospheres, and cooled at one atmosphere of absolute pressure, the upper and lower limits of absolute temperature bear to each other the proportion of 1.58 to 1, and the theoretical efficiency is about 0.37. In a steam engine working between the same limits of pressure the theoretical limits of temperature on Fahrenheit's ordinary scale would be about 296 deg. and 212 deg.; corresponding on the absolute scale to 757 deg. Fahr., and 673 deg., and the theoretical efficiency would be equal to $84 \div 757 = 124$. It is easy to see in a general way that in an engine in which the fluid employed consists of air and steam mixed, the efficiency will be something intermediate between the quantities above set down, being less than that in which air alone is employed, and greater than that in which steam alone is employed. The most efficient engine of all, theoretically, would be one in which nothing but dry air was employed. Here we are met by the fact that great practical difficulty has been found to attend the employment of dry air, in particular that it has been found almost impossible to prevent the heating vessel from becoming overheated, and consequently burned. On the other hand, an engine worked with steam alone is liable to fall considerably below the calculated theoretical efficiency, from the cause already mentioned, amongst others. There is a certain proportion of air to steam which enables all the heat required for raising the temperature to be produced by the compression of the air, being the surplus over and above that which is required in order to raise the temperature of the air itself, and thus the efficiency of the engine is prevented from falling materially below the calculated theoretical efficiency for steam. In the examples already given the compression of dry air to 5 atmospheres would produce a rise of 390 deg. Fahr., while the actual rise required is only 84 deg. Fahr., and without going into a minute calculation of the surplus heat produced by the compression of the air, it may be mentioned as the result of such a calculation, that the surplus heat so produced amounts to about three-fourths of the whole heat due to the compression, and that by introducing a mass of air at each stroke, equal to about one and one-third the mass of feed-water employed, the whole heat necessary for raising by 84 deg. Fahr. the temperature of the air and water may be obtained by compression of the air alone, to the great benefit of the efficiency of the steam.

The above example appears to be sufficient to show that it is worth while in what have lately been called aero-steam engines, to carry experiment further than has hitherto been done in the direction of the introduction of large quantities of compressed air. The example is applicable to non-condensing engines only; but the same kind of reasoning could be extended to condensing engines also, only taking care to provide a sufficiently large air pump. It may be added that the aggregate volume of air and steam

required in order to produce a given power would be nearly the same with the volume of steam alone, required for the same power, with the addition of a volume equal to that of the air-compressing pump.

THE USE OF WATER GLASS IN BUILDING.

From "The Building News."

On this subject H. Wagner, of Pfiffligheim, remarks, in the "Hesse Trade Circular," that four kinds of water glass are used —potash water glass, soda water glass, the double water glass (a combination of equal parts of potash and soda with silica), and fixing water glass. For the technical application of double water glass, it is sufficient to mix 3 parts of concentrated potash water glass with 2 parts of concentrated soda water glass. The fixing water glass is a potash water glass completely saturated with silica, to which a portion of soluble soda silicate is added, that is, to 3 parts of concentrated potash water glass, one part of soluble soda silicate. The latter is prepared by fusing together 3 parts of pure anhydrous carbonate of soda with 2 parts of powdered quartz, and making a concentrated solution of it. The fixing water glass has the great advantage of producing no efflorescence of carbonate of soda, and the coating is clean and free from spots, on which account it is preferred for ornament and internal decoration. In coating with water glass, it is important to consider the degree of dilution, and the proportions given here should be modified according to circumstances. Whatever be the kind of water glass, that of 33 deg., diluted with twice its weight of rain or river water, should be used for the first coat, but with equal weight of water for the second and third coat. Water glass of 66 deg. is diluted for the first coat with 5, for the second and third with $2\frac{1}{2}$, parts by weight. These proportions are retained for sandstones and bricks. Upon a surface of 100 square metres, the following proportions are required:

For 1st cost,	4 lb.	of water glass of	33 deg.	and 12 lb.	water.
" 2d "	4 lb.	"	33 deg.	" 8 lb.	"
" 3d "	3 lb.	"	33 deg.	" 6 lb.	"

To produce a fine and durable coat of water glass upon a wall, special regard must be had to the dressing. The problem is to give it a stone-like solidity, and to fuse it evenly with the wall, taking care, at the same time, that the water glass shall soak uniformly into every part. In order to obtain this, the mortar should be more thin than fat; the water glass would penetrate with difficulty into limy mortar, and cause also cracks, which should be avoided.

This must be well dried and exposed for a longer time to the air, to be converted into a subcarbonate of lime, because otherwise the quick-lime would partially decompose the water glass. The wall thus prepared is saturated with soda or double water glass of 33 deg., using the same process of dilution for each coat as above given. With larger surfaces small rain spouts are used, from which the jet is distributed like fine rain by being forced through a strainer provided for the purpose. This operation may be repeated two or three times, taking care, however, that the pores of the wall are not closed by a too frequent charge, or too concentrated solutions, and thus become unfit to receive the colors.

In order to secure a good uniform ground, a water glass mortar should be prepared in the following manner: 10 parts of sharp dried sand, and 3 parts of quick-lime, slaked in the air (by sprinkling fresh burnt lime with water, and frequent stirring till it is reduced to a fine powder), are mixed with 2 parts of chalk, or limestone, powdered quite dry and passed through a moderately fine sieve; then this mixture is worked into a plastic dough with a soda water glass of 33 deg., diluted with 2 parts of water, so that it can be applied like ordinary mortar for dressing. This mortar does good service, also, in the joints of brick walls, and wherever it is important to guard against air and damp. It will differ from this according as more sand or chalk is added, and in many cases also the water glass solution employed is more concentrated. After drying, which takes a few days, it becomes stone hard, and should be saturated repeatedly in the manner described, with a solution of soda water glass (which is cheaper than potash water glass, and for this purpose quite sufficient).

When the foundation is laid in one way

or the other, after drying, the coating with color may be proceeded with. The colors to be applied, before they are brought in contact with the water glass, are moistened with sufficient rain or river water without rendering them liquid. The more plastic and uniform this color paste is, the better it mixes afterwards with the water glass, and the less fear there is that the color will curdle.

Even when the different coats are laid on as prescribed, the double water glass should be used. After 24 hours a fresh coat may be applied, and to prevent an efflorescence of carbonate of soda, it is advisable to give the last coat, with fixing water glass. In order to impart a certain gloss like oil paint, the last coat, when dry, is gone over with a very dilute solution of fixing water glass, taking care that those parts which imbibe slowly present a uniform appearance. The choice of the various colors is by no means indifferent, as many have so close an affinity to water glass that they are no sooner in contact than they curdle at once to a useless mass, as often happens with the commercial oxide of iron, when, after its preparation, it still contains free sulphuric acid. Other colors are materially changed in their tints; for this reason, none of those colors derived from the organic kingdom should be used, as they fade sooner or later.

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—A regular meeting of this Society was held at its rooms in New York, Wednesday evening, Dec. 10th.

"A Record of some experiments showing the Character and Position of Neutral Axes, as seen by Polarized Light," by Louis Nickerson, C. E., of St. Louis, Mo., was presented and discussed.

During the researches of Eaton Hodgkinson, published in 1842, he took the ground that the neutral axis in a beam shifted as the load was increased, and finally took position where the compressive strength of the material above it would be equal to the tensile strength of that below it.

He fixed this for a cast-iron rectangular beam about to break at one-seventh its depth from the top, because its resistance to tension was one-seventh that to compression, and this was apparently proved by an inspection of the fracture of beams which were broken. In 1855, Henry Barlow made experiments to test this theory, in the course of which he claims to have established that the neutral axis of a rectangular beam always lies through the centre of gravity of the section, and recognizes in addition to the tensile and compressive elements of strength in a beam, a third, due to the lateral adhesion of the fibres, and increasing with the deflection.

Each takes the transverse strength of a cast-iron beam at about 2½ times as great as it should be, according to its tensile and compressive strengths, and records a theory in regard to the character and position of the neutral axis, differing from the other.

The experiments here recorded were made to reconcile the results obtained by Messrs. Hodgkinson and Barlow, and to discover whether the "Lamination of Material in Planes normal to the direction of the pressure excited upon it," was due to a periodic action of force, or consequent upon tangential stress, imperfect cohesion of the material, or the running together of internal cells. Polarized light was sent through plates of glass under compression, either as beams or columns.

The difference in the effects caused by similar strains on two materials is relative; and that produced by a force upon glass is like that upon other substances.

The results sought for are from certain general laws of the doctrine of forces, which must be the same for all materials, and modified, not changed, by any particular one; the transparency of glass and its bi-refractive quality when strained exhibits them to the eye.

In the experiments, structural differences were ignored. Glass, cast-iron and steel are amorphous bodies, yet composed of segrated crystals, and under pressure exhibit a similar characteristic fracture. There is also a like ratio between this compression and tensile strength—that of glass appearing to be a mean of the other two.

The apparatus used was the one common for experiments with polarized light; a polarizer of glass plates; an analyzer of one plate blackened at the back; and a small brass clamp with thumb-screw to compress the pieces of glass experimented upon, either as beams or columns.

These pieces, before pressure is applied, appear black in polarized light—glass in an unstrained or neutral state being impervious to it.

A slip, representing a beam, placed in the clamp and the screw slightly tightened, shows at the top and bottom a clear space, enclosing a dark space; between which, under greater pressure, take sharper outlines; and colored curves, distinct and separate, appear, following the lines of strain. These increase in number and brilliancy with the pressure and always move towards the dark and neutral space.

The experiments were made in consecutive steps; the application of force ranging from proportionately a very small tensile with a very large compressive strain, to that where the two were nearly alike, and were described at length.

Colored drawings, representing the effects of polarized light upon the various slips of glass experimented with, were exhibited.

The results obtained show that the neutral axis is a flexible line, or plane, truly parallel to the top and bottom sides of the rectangular beam, and passing through the centres of gravity of its sections, *only* when the load is evenly distributed from end to end, or when the beam is infinitely long; and that when there is a local pressure, the neutral axis is more or less governed in its direction and form, by the strain passing from the point of local pressure towards the points of the support.

The beams of Mr. Hodgkinson were broken at the centre by a blow, in which the neutral axis was located above the centre of gravity of the transverse section. From these experiments it is deduced that this position is due to the application of the force, and not to the ratio of the tensile to compressive resistance.

In comparison with Mr. Hodgkinson's, Mr. Barlow's beams were, in proportion of length to depth, one-half longer, and he naturally found the neutral axis more nearly horizontal and less distorted.

Glass beams, in length fourteen times the depth, show the neutral axis so nearly horizontal, that he may have overlooked the variation, and it must be almost imperceptible in beams more in length than ten times the depth.

It is claimed that the neutral axis, as exhibited by polarized light, from the cohesion of material or other cause, is extended to a breadth, and cannot become a true line, until, in reference to the cohesion, the tensile and compressive forces are infinite. Also that its longitudinal direction, like the directions of lines of strain, is not an arbitrary one, but resultant from the relative qualities and quantities of all the forces in the beam—its evident place in Physics being that of still water between opposing eddies or vortices.

The pulsations of completely polarized light are confined to two directions at right angles to each other.

In the drawings are represented two images of the same object, corresponding to these two directions, one being taken, and the analyzer revolved 90 deg. for the other; they, for convenience termed positive and negative images, are pictures of strains in the beam or column normal to each other. In the first tubular bridges, a wave of "buckling" always followed a line 45 deg. from the top where the load was placed, even crossing the stiffening plates. Such strains may be called "strut strains," and their resultant in a beam is vertical. The principal strains in an ordinary beam are horizontal or "flange strains," being tension in the bottom and compression in the top. Their resultant is also horizontal and normal to the first.

The drawings show that when the "strut" or "flange" strains increase, correspondingly the negative or positive images, as the case may be, grow brighter.

Many strains may exert in the same beam, crossing and there neutralizing each other, and yet elsewhere be individual and intact.

As glass is pervious to polarized light when strained, and impervious when unstrained, the light parts must be strained in proportion to their brightness, and the dark unstrained or neutral; as bi-refraction is caused by strain, both must be governed by the same laws; further, the resultant angles of the strains, and those of polarization are rectangles, and as the strains change in character, so do the polar images change in correspondence; therefore the images are pictures of the strains.

Any space, which is under no strain, whatever load is applied to the beam, must remain dark, under all revolutions of the analyzer; each marks the crossing of the two resultant axes, that of the "strut" and of the "flange" strains.

The appearance of light around the neutral band is the first symptom of distortion in the positive image; soon faint segments of yellow appear at the bottom, occupying a large part of the space between the supports, and at the top varying with the application of the load.

As the pressure is increased, the yellow from both edges moves forward towards the neutral band, becomes a zone, and a segment of red succeeds. Both continue to move until the red becomes a zone, and is followed by a segment of blue, between which and the red there is a dark neutral line.

A second similar series may be brought out before fracture.

Mr. Barlow established the existence of a third and important element of strength in a beam, which increases as the beam is bent. The moment of this or bending resistance, is equal to that of the applied force, or bending stress, and their common line moves towards the primary neutral axis as the load is increased; this is shown by the dark lines described.

There are then neutral axes existent, amidst disturbing forces, of a beam which, under increasing loads, shortens in the top and lengthens in the bottom.

A transparent column under pressure exhibits a series of colored rings—glass showing from three to six at each end—and a softer material, as copal, wreaths of colored bands from top to bottom, a dark space always occurring between the blue and red, which marks an unstrained part of the column, or a union of equal and opposite forces.

To determine what these dark rings indicated, tests were made upon columns, which changed in form under pressure; these were brass tubes $\frac{4}{10}$ in. exterior, $\frac{3}{10}$ in. interior diameter, and about $1\frac{1}{2}$ in. long.

Submitted to compression until they assumed a permanent form, they all exhibited from end to end a series of extended rings, uniformly separated, or periodic waves. Other steel tubes also compressed were examined and an empiric expression derived, which will locate any wave in relation to another, the tube being homogeneous.

Hollow columns, if sufficiently under stress, within elastic limits, may be greatly strengthened by bands placed where these waves would otherwise occur; it is inferred that one-third additional material will thus double the strength of the column. In conclusion, the law of periodicy of force in compression, and probably in tension, seems to be proved, and the law of lamination under pressure accounted for.

DISCUSSION.

Mr. Macdonald—"The experiments upon which formulæ in common use for the proportion and strength of beams are based, were made upon cubes of the materials tested, and it is found that the constants derived are inapplicable to ordinary cases in practice."

Mr. Boller—"A recent comparison of various standard formulæ for the strength of beams, made by taking a given beam and calculating with each formula its safe load, gave as follows: Two 25 tons, one 30 tons, and one 37 tons. The last was from Mr. Baker's formula, in which he has introduced the resistance due to flexion; the beam taken was 3 in. × 6 in. and 5 ft. long. Engineers should know more of the strength of materials. The formulæ used involve the application of constants ranging variously from maximum to minimum

strength; these often differ widely, and therefore give uncertain results."

Mr. Macdonald.—"It is known that a beam, loaded so that its outer fibres by formula should be under a maximum strain, will stand a greater load.

"The constants employed in calculating the strength of a beam should be determined from experiments upon a similar beam of the same material, and not those given for direct tension and compression."

Prof. De Volson Wood—"The point of greatest interest to him in the paper read is whether the neutral axis is a line or a space, as water in an eddy.

"In regard to the neutral axis and strength of beams as determined by ordinary rules, the fact is, if we assume in a bent beam that the extensions and compressions are proportional to the distance of the elements from the neutral axis, and take the modulus of tenacity or of crushing, as the case may be, for the modulus of rupture of the beam, a beam proportioned in accordance therewith will have an excess of strength.

"Thus take a rectangular cast-iron beam, as the best example in practice; according to theory, the mean value of the modulus of rupture should be 16,000 lbs., but it is seen by experiment to be 36,000 lbs.

"Former writers do not explain this discrepancy but simply admit a defect in the theory.

"Mr. Barlow detected a new element of strength, which he called 'Resistance to Flexure,' a term which is unfortunate, as all the forces in a beam which resist bending are resistance to flexure. 'Longitudinal Shearing Resistance' is a better term, and one now used.

"This force is the resistance of the fibres to being drawn over each other. If there was no such resistance the fibres would retain their original length.

"He found by a critical examination of iron beams, that the transverse sections remained normal to the neutral axis, during flexure, thus proving the existence of a force besides that which produces direct elongation and compression.

"This is the longitudinal shearing resistance. Mr. Barlow also determined the laws governing it at rupture, and modified the formulas accordingly.

"His experiments are the most weighty and valuable of any made upon beams, as far as theory is concerned. His formulas and constants agree with the actual strength for all sections which he used.

"It is evident the ordinary law, that strains vary as their distance from the neutral axis, cannot apply to beams of I section; for, that it may apply, there must be at least a continuity between all the elements of the flanges and the web.

"Mr. Barlow's formula for this case cannot be correct. In all I sections there is a peculiar combination of the strains about the angles where the flanges and web join.

"Prof. Norton, by direct experiment, determined the fact of a transverse shearing resistance in beams and the laws governing it in those of rectangular section. The deflections due to longitudinal and transverse shearing resistances, tend respectively to diminish and increase that defined by Navier's theory.

"Simple rules cannot be given applicable to the varied forms of beams in use. Constants deduced from experiment upon solid rectangular beams will, doubtless, apply to solid beams of all dimensions, but not to others."

Mr. Boller—"It is best to make a beam proportioned similar to those to be used, break it and deduce therefrom a constant.

"The formulas for I beams are safer for thin than thick webs, say ¼-in. web and 4-in. flange."

Prof. Wood—"The experiment of Baron Von Webber showed that the web had never been made too thin; where the flange and web are joined there should be a large curve."

Mr. Macdonald—"In T. C. Clarke's description of the Quincey Bridge there is a statement that 12-in. I floor beams 15½ ft. long suspended in pairs from pannel points about 12 ft. apart, and carrying a single track of 4 ft. 8½ in. gauge, scarcely deflected under a maximum engine load, which caused a strain upon the outer fibres, at least equal to 14,000 lbs. per sq. in. according to formulas in general use."

Prof. Wood—"Structures should not be proportioned in reference to the ultimate strength of the parts, but their elastic limits. Some very tenacious irons have a low limit of elasticity, while in other cases certain grades of steel for instance, elasticity is preserved under a strain equal to one-half the tensile strength."

The Secretary presented communications upon Mr. Nickerson's paper, from Gen. Barnard, Col. Merrill, Messrs. McAlpine and Fuertes, reading of which and further discussion were deferred until the meeting to be held February 19th next.

SOCIETY OF ENGINEERS. (London.)—A paper was read on "Continuous Railway Brakes" by Mr. W. H. Fox. The author, in the first place, considered the conditions which a continuous brake should fulfil, and which he set forth in detail. He then investigated the retarding force required to stop a train within a given distance, which, he showed, varied greatly under the varying conditions of railway traffic. His general conclusion, however, was that a retarding force of 18 per cent. of the weight of a train travelling at the rate of 60 miles per hour would stop it within a distance of 220 yards in ordinary weather. The author then discussed the question of wood *versus* cast-iron brake blocks, his opinion being that cast-iron blocks were the better of the two, because with them the friction was more constant than with wood blocks, and was higher in foggy and wet weather, when brake power was most needed. Mr. Fox then went on to describe, by the aid of a set of elaborate diagrams, the chain brake of Messrs. Wilkin & Clarke, and the hydraulic brake of Mr. Barker, pointing out the relative advantages and disadvantages of each system. The author considered that every locomotive and carriage should be fitted with sufficient brake power to enable a train running at the rate of 60 miles per hour, on a level line, to be brought to a state of rest within a distance of 220 yards in ordinary weather. He further advocated the interference of the legislature in compelling this, on the score of public safety. The limits of a paper not permitting the author to describe all the systems of brakes in practical operation, he observed that, having been able to describe only a chain and hydraulic brakes, he reserved descriptions of the atmospheric and

electric brakes for a second paper. An animated discussion followed the reading of Mr. Fox s very practical paper, in which several railway engineers and others interested in the promotion of public safety in railways took part.

MR. M. P. THOMAS, acting under instructions from the Paris Society of Civil Enginers, has recently presented to that body a report upon the oxy-hydrogen light. The conclusions arrived at are the following: (1) Theoretically, the combustion of oxygen does not increase the illuminating power of a given volume of gas. (2) Practically, however, it enables a burner to consume four times the quantity of gas that can be burned in air, without detriment to the utilization of the light which may be developed. In particular, it utilizes the entire luminous capacity of the gases, however rich, and in almost any quantity. Consequently, it would be disadvantageous to employ it for ordinary street-lightning, on account of the limited quantity of gas consumed by the burners, the only advantage gained being the beauty of the light, provided the gas is very rich. But it is very disadvantageous for great centres of light (sunburners, etc.), where a large volume of gas is to be consumed without loss.

IRON AND STEEL NOTES.

SHAW'S METHOD OF PURIFYING IRON.—Mr. Thomas Shaw, 913 Bridge Avenue, Philadelphia, has a patented process for the purification of iron and steel, which is thus described by a correspondent of the "U. S. R. R. and Mining Register:"

"To a cupola furnace fully charged and at white heat, he applies a nozzle so shaped as to receive a strong jet of dry steam at such an angle as to throw the entire mass of metal into drops—in fact, into spray, and yet give the shower a definite and nearly horizontal direction. The floor of the receptacle must be a proper one for melted iron, and divided into sections or *bins*, so as to separate the falling metal into four divisions. That which lies nearest the nozzle will be common cast iron; that in the second bin will be fine cast iron; that in the third will be true cast steel; and the fourth will contain soft hoop iron ready for the hammer. And this result, observing the directions here given, can be continued with certainty the day through and the year round."

We are unable to speak of the process from personal observation, but we submit it to our readers, so that any who are interested may make such inquiries of Mr. Shaw as they think expedient.

ESTIMATION OF SULPHUR IN IRON AND STEEL.—The more common method of estimating sulphur in iron and steel consists in acting on the metal with sulphuric or hydrochloric acid, and precipitating some metallic sulphide by the evolved sulphuretted hydrogen. It would be a desideratum, in point of time, if this sulphide could be directly weighed.

By passing the evolved gases through an ammoniacal solution of cadmium oxide (or a solution of sulphate to which an excess of ammonia has been added), a precipitate of cadmium sulphide is obtained which can be at once collected upon a small filter, dried at 212 deg. F., and weighed.

The phosphoretted hydrogen, evolved in the solution of the metal together with the sulphuretted hydrogen, causes no precipitate in the solution.

The presence of ammoniacal salts would also prevent any precipitation of carbonate of cadmium by the traces of carbonic acid in the air drawn through the apparatus by the aspirator after the metal is dissolved. However, the aspirated air could easily be passed through potash solution, to remove its carbonic acid.

To prevent the precipitation of oxide of cadmium on the filter, the precipitate should be washed with distilled water containing diminishing quantities of ammonia.

If, in very accurate estimations, it is necessary to estimate the minute quantity of sulphur left in the solution and residue of the metal, this can be done as usual and added to that found as above.

Five test analyses of a piece of Bessemer steel known to contain about 13 per cert. sulphur, gave as follows:

1st	124 per cent.
2d	124 "
3d	137 "
4th	125 "
5th	124 "

Cambria Iron Works, Johnstown, Pa., Oct. 12, 1872.—*American Chemist*, November 1873.

WHAT IS STEEL?—Mr. A. L. Holley in his lecture before the Stevens Institute, says: "Before considering the process and machinery, let us define the term steel. Steel is an alloy of iron which is cast while in a fluid state into a malleable ingot. Any radical nomenclature founded on chemical differences leads to endless mistake and confusion. If steel is defined as an alloy of iron containing carbon enough to harden it when it is heated and plunged into water, then puddled iron, although laminated and heterogeneous in structure, may be steel, and the finest product of the crucible, although crystalline and homogeneous in structure, may not be steel. The fundamental and essential difference between steel and all other compounds of iron, is a structural difference, and it is always easily determined, while steel and wrought iron cannot always be distinguished by chemical analysis. The same proportions of carbon, manganese, silicon, and other elements, may exist in and similarly affect any malleable alloy of iron. Steel is, therefore, an alloy of iron which is cast into a malleable mass."

TEMPERING STEEL.—Siegfried's process of tempering steel is attracting quite a degree of attention. He describes it as follows:

"I first heat the steel to a cherry red in a clean smith's fire, and then cover the steel with chloride of sodium (common salt), purifying the fire also by throwing in salt. I work the steel in this condition and while subjected to this treatment, until it is brought into nearly its finished form. I then substitute for the salt a compound composed of the following ingredients and in about the following proportions: One part, by weight, of each of the following substances: chloride of sodium, sulphate of copper, sal ammoniac, and sal soda, together with one-half part, by weight, of pure nitrate of

potassa, said ingredients being pulverized and mixed. I alternately heat the steel and treat it by covering with this mixture and hammering until it is thoroughly refined and brought into its finished form. I then return it to the fire and heat it slowly to a cherry red, and then plunge it into a bath composed of the following ingredients in substantially the following proportions for the required quantity: of rain water, 1 gallon; of alum, 1½ oz.; of nitrate of potassa, 1 oz; and of chloride of sodium, 6 oz. These quantities and proportions are stated as being what I regard as practically the best; but it is manifest that they may be slightly changed without departing from the principle of my invention."

This system has lately been adopted in the Government shops, and Congress has appropriated $10,000 to pay for the right. It is claimed to be the best method of tempering steel so far discovered---*The Mining Journal.*

RAILWAY NOTES.

NARROW GAUGE.—*American Fork Railway.*—The profile of this railway is interesting as showing a line that has probably the heaviest grade of any in the world. The railway is constructed 16 miles from the terminus at American Fork to Deer Creek, in the canyon, and within 6 miles of the smelting works, and withing 1¾ miles of the famous Miller mine. The elevation of the smelting works above the junction of the railway with U. S. R. is 2,684 ft., which has to be attained in 19 miles. The heaviest grade, within the first 4 miles, reaches 297 ft. to the mile.

Baltimore Projects.—A contract has been awarded for the construction of a narrow-gauge railway between Baltimore and Townsontown. A survey is being made for a similar railway between Baltimore and Ellicot City.

Colorado Central.—Mountain Extension Business.—Says the "Golden Transcript:" The rolling stock of our railways has been taxed to its utmost, forwarding material for the superstructure up North Clear Creek. Only by running night and day has the Company been able to forward the freight for that region, and still a large quantity has accumulated here. Now, with the completion to Black Hawk, the Company will be enabled to clear their depot here at once and forward all incoming freights as fast as they arrive, besides forwarding large quantities of coal to the mountains, the need for which is severely felt.—*Chicago Railway Review.*

THE NARROW-GAUGE EXPERIMENT.—There are few topics which interest the people more than narrow-gauge enterprises in this State. It is the problem of cheap and substantial roads adequate to the public wants. In Santa Cruz County, a subsidy of $6,000 a mile was recently voted, and it was hoped that this amount, increased by private subscriptions, would insure the building of a narrow-gauge road from Watsonville to Santa Cruz, 20 miles, and thence to the north line of the county to connect with a proposed railway through San Mateo County. If there was a narrow gauge railway from Watsonville to Santa Cruz, freight might be sent out of the Pajaro Valley to Santa Cruz, and thence shipped by water to San F. at $1.50 a ton less than the rates now charged by railway; the difference would probably be even greater.

The Stockton people have secured private subscriptions of $110,000 for a narrow-gauge between that town and Visalia; the latter town has also made some headway with a subscription. The future prosperity of Stockton depends on the accomplishment of this project. Something has got to be done to centralize business at that point. Stockton lost one grand opportunity, when instead of a railway terminus or connection in that city, it was pushed over to the west side of the valley, 15 miles. The people want a railway down the east side of the valley, which in no sense would be competing with the one now on the other side, but distant from it from 8 to 12 miles, intersecting the best wheat region of the valley, and keeping near to the foot hills, where the resources are as great as in the valley.

The difference in facilities for two years between a railway and none, would represent enough money to build the railway. The farmers and business men by saving their prospective losses, can put that railway in operation for 75 miles within the next six months.

There is no such thing as building narrow-gauge roads on paper. They are home enterprises to the extent at least of $6,000 a mile. There is not an acre of wheat land within six miles of the narrow-gauge railway contemplated between Stockton and Visalia, which will not double in value if the railway is constructed.—*San Francisco Bulletin.*

ENGINEERING STRUCTURES.

THE Cleveland Lake tunnel, which was 4,000 ft. from the shore in April, 1871, was then interrupted by the breaking in of water. Work was then commenced from the crib in the lake where, after four months, soft clay was met with, and a hydraulic shield and press had to be provided. In April, 1872, work was again resumed, the soft clay passed, and progress is now at the rate of about 70 ft. a week. The work done is 4,000 ft. from the shore and 950 ft. from the crib; about 1,650 remains to be cut through. These details are furnished to the "Journal of the Franklin Institute" by Mr. Joseph McDonell.

THE ST. LOUIS BRIDGE.—From an article in the St. Louis "Globe' we take the following: The investigations of years in regard to the under-current of the Mississippi have shown that no river in the world changes its bed so rapidly and to such an extent. It proved necessary, then, to lay the foundation of the piers upon the rock itself, which under one pier is 90 ft., under the other 120 ft. below the usual high-water line. The base is laid upon the rock by means of immense iron caissons. The bridge itself will rest upon 4 piers. They will carry 3 arches, the principal one measuring 520 ft. in length, and the other 500 ft. The whole length, measuring from the Illinois abutment to Washington avenue in St. Louis, will be 2,230 ft., and it will cost $4,496,953 (estimated). The contracts already made with the different railway companies secure to the bridge company an aver-

age tariff of 65 cents per ton, thus yielding from freight alone a yearly revenue of upward of $500,000. From other sources it is estimated that not less than $300,000 will be received, making a total revenue of at least $800,000, which will be equal to 8 per cent. on a capital of $10,000,000. The bridge is to be built of cast steel, and experiments have been made to test the strength of the metal, and no possible precaution will be neglected to insure perfect success.

Contemporaneous with the completion of the bridge across the Mississippi will arise the necessity for a union passenger depot in St. Louis to accommodate the several railroads leading into that city. The building will be 4 stories, with a Mansard or French roof. A hotel will provide accommodations for the travelling public in the upper stories. The part devoted to the use of the railroads will be complete in every particular. It is proposed to use the smoke-consuming engines for the purpose of running the trains into and out of the tunnel and depot. The floors will be deadened and the trains operated by signals, thus removing all source of inconvenience to the occupants and guests.

ORDNANCE AND NAVAL.

AMERICAN CHAIN CABLE TEST.—Samples of American Chain, furnished by Bradlee & Co., Empire Chain Works, Philadelphia, were tested, a few daye since, on the machine made by Riehle Bros., of the same place, with the following results:

	LBS.
½ in. chain broke at strain of.....	15,750
⅝ " " "	27,000
¾ " " "	37,500
1¼ " " "	100,000

According to Rankine on ship-building, "the ultimate capacity of good cable chain equals 750 lbs. per circular ½ in., or 27,3-10 tons per sq. in., in form of straight cylindrical bolts." According to this rule,

	LBS.
½ in should break at.....	12,004
⅝ " " "	18,755
¾ " " "	26,910
1¼ " " "	75,034

The chain tested, the data of which we have given, stood an *excess* of strain over the rule figures, as follows: ½ in., 3,746 lbs.; ⅝ in., 8,245 lbs.; ¾ in., 10,590 lbs.; 1¼ in., 24,966 lbs. These samples were from lots made for Mr. Ward, of Detroit, Mich., and were from the same quality and make of iron as this establishment uses in all its work.

We do not see why American chains should not be better than English. Certainly, the workmen have the same amount of skill here as there, and our iron is superior. It is claimed that, if Congress would grant vessels using American-made chains a bounty equal to the duty on English chain, establish a standard of test, and have inspectors to see that the rules were complied with, and stamp the chain when tested, we would soon gain the first rank in this industry, at home as well as abroad. The tests we have referred to were made in the presence of disinterested parties, and we put them on record as being valuable.—*Nautical Gazette.*

UNITED STATES NAVY LIST.—The following is a list of vessels of the U. S. Navy now in commission and fitting out, and their present station:

Asiatic Station.

Name.	*Guns.*	*Station.*
Hartford, s. s.....	18	Gibraltar, Nov. 28.
Lackawanna, s. s...	10	Shanghai, Oct. 18.
Iroquois, s. s.....	6	Shanghai, Oct. 13.
Ashuelot, p. s.....	6	Tien-tsin, Sept. 17.
Monocacy, p. s.....	6	Shanghai, Oct. 22.
Saco, s. s.....	3	Shanghai, Oct. 22.
Yantic, s. s.....	3	Aden.
Palos, s. s.....	6	Shanghai, Oct. 2.
Idaho, s	†7	Yokohama.

European Station.

Wabash, s. s.....	45	Nice, Nov. 28.
Brooklyn, s. s	20	En route to Naples, Nov. 1.
Congress, s. s.	16	Malta, Nov. 20, bound east.
Plymouth, s. s	12	Nice, Nov. 28.
Shenandoah, s. s....	11	Marseilles, Nov. 17.
Wachuset, s. s.	6	Nice, Nov. 28.

North Atlantic Station.

Worchester, s. s....	15	Key West, Nov. 29.
Richmond, s. s.....	14	Arrived at Norfolk, Dec. 19.
Canandaigua, s. s...	10	Key West.
Wyoming, s. s.....	6	Key West, Dec. 15.
Shawmut, s. s	3	Key West.
Terror, i. c.....	4	Key West.
Nipsic, s. s.....	3	C Haytien, Nov. 27.
Pawnee, s. s.....	†2	Pensacola.
Saugus, i. c.....	2	En route to Key West, Dec. 2.

South Atlantic Station.

Lancaster, s. s.....	22	Montevideo, Dec. 1.
Ticonderoga, s. s...	11	Montevideo, Dec. 1.
Wasp, p. s.....	1	Montevideo, Dec. 1.

Pacific Station.

California, s. s.....	21	San Francisco, Nov. 13.
Pensacola, s. s.....	22	Sl'd Valparaiso, Oct. 30.
Benicia, s. s.....	12	Sl'd for Sandwich I, Dec. 7.
Saranac, p. s.	11	San Francisco, Nov. 23.
Omaha, s. s.....	12	Sailed, Funchal, Nov. 21.
Tuscarora, s. s.....	6	Callao.
Narragansett, s. s...	5	Cruising S. Pacific.
Onward, s	3	Store ship, Callao, Peru.

Fitting for Service.

Monongahela, s. s...	11	Portsmouth, N. H.
Juniata, s. s.....	8	Fitting at Boston.

Homeward Bound.

Colorado, s s.....	45	En route to N. Y.
Alaska, s. s.....	12	Ordered to N. Y.
St. Mary's, s.....	16	Sailed for Norfolk, Nov 20.

Special Service.

Powhatan, s. s.	17	En route to Key West.
Kansas, s. s.....	3	Arrived at Key West, Dec. 10
Portsmouth, s.....	51	Sailed Dec. 21.
Guard, s.....	4	Fitting at N. Y.
Supply, s	†6	Fitting at N. Y.
Michigan, p. s.. ...	†8	On the Lakes.
Frolic, p. s.....	†8	V. A. Flag-ship, New York.
Tallapoosa, p. s	—	Special Navy Yard duty.
Constellation, s.....	10	Practice-ship, Annapolis.
Santee, s.....	49	Gunnery ship, Annapolis.
Dale, s.....	8	Practice-ship, Annapolis.
Saratoga, s.....	8	Naval Academy.
America, y.....	—	Naval Academy.

Receiving Ships.

New Hampshire, s..	15	Norfolk, Va.
Ohio, s.....	5	Boston, Mass.
Vermont, s.....	16	Brooklyn, N. Y.
Independence, s.....	22	Mare Island, Cal.
Sabine, s.....	36	Portsmouth, N. H.

† Howitzers.

—*Nautical Gazette.*

BOOK NOTICES.

ONE LAW IN NATURE, a new Corpuscular Theory comprehending Unity of Force, Identity of Matter and its Multiple Atom Constitution. By Capt. H. M. LAZELLE, U. S. Army. New York: D. Van Nostrand.

The author of this essay takes a step in advance of the doctrine of the correlation of forces and proclaims their identity. He reasons throughout from the observed facts of science, and bases his doctrine upon the accepted statements of phenomena as proclaimed in the latest records.

The range of subjects presented is briefly stated in the following heads of chapters: I. Introductory. II. Force in General—Attraction of Gravity. III. Primary Force. IV. Primary Force is a secondary cause, invariable and perpetual. V. Of, matter and its multiple-atom constitution. VI. The Nebular Hypothesis. VII. The Perpetuation of Energy. VIII. Interchange of dynamic energy. IX. Interchange of primary force, and the polar relations of Atoms and Masses. X. Heat and Light Motion. XI. Electrical phenomena under one primary force, and the multiple-atom constitution of matter. XII. Magnetic manifestations. XIII. Mode of Chemical Energy under one primary force. XIV. Vital phenomena as resultants of primary force and dynamic energy.

AN ARCHITECT'S NOTE-BOOK IN SPAIN, principally illustrating the domestic architecture of that country. By DIGBY WYATT, M. A. London: Autotype Fine Art Co. For sale by Van Nostrand.

The illustrations of this fine work appear like sketches in ink as made by the artist on the spot. They are in reality faithful reproductions of the same by the Autotype process. As studies for young artists and architects these illustrations are exceedingly valuable. But as correct renderings of the architecture of this romantic corner of the earth, from such an authority as Digby Wyatt, they bear a higher value still.

The architecture represented in the full-page plates, one hundred in number, is that of many cities and towns, among which are Burgos, Valladolid Leon, Salamanca, Avila, Segovia, Toledo, Seville, Cadiz, Malaga, Granada (The Alhambra), Guadalaxara, Saragossa, Barcelona, and Gerona.

A NEW AND COMPLETE SET OF TRAVERSE TABLES FOR EVERY MINUTE OF THE QUADRANT AND TO FIVE PLACES OF DECIMALS. By Major-Gen. J. T. BOILEAU, F. R. S. London: W. H. Allen & Co. For sale by Van Nostrand.

The above title contains sufficient explanation of the design of the book.

A traverse table to single minutes has been widely demanded for the last few years, but was with difficulty obtained. The original edition was printed in 1839, and the few copies in this country were held at high prices by their owners.

This new edition will relieve a want which of late has seemed quite urgent. D. Van Nostrand.

A TREATISE ON WATERWORKS FOR THE SUPPLY OF CITIES AND TOWNS. By SAMUEL HUGHES, F. G. S. London: Lockwood & Co.

This is a new edition of a work prepared in 1856 for the Weale Series. It is considerably enlarged and the value of the treatise thereby largely increased.

The subject is divided into Parts, the first of which treats of the old and new methods of collecting supplies of water.

Part 2d treats of the origin of springs and the characteristics possessed by them severally when flowing from the various geological strata.

Part 3d describes briefly the systems belonging to some twenty English towns, giving a more complete description of the supply of Liverpool.

Part 4th describes boring processes and the machinery therefor.

Part 5th treats of pumping engines.

Part 6th is devoted to natural and artificial reservoirs.

Part 7th is devoted to the different methods of measuring the flow of water in rivers, canals, aqueducts and pipes.

There is also an appendix of valuable tables. Altogether there is a large amount of information in a small book.

PRACTICE AND THEORY OF NAVIGATION AND NAUTICAL ASTRONOMY. By WILLIAM CULLEY BERGEN. London: R. H. Laurie.

This voluminous work is designed as an aid to the young student in navigation who can get no other instruction.

The simplest problems are solved at length, every step of the process being worked in full. Examination questions in all subjects relating to practical navigation and for all grades of proficiency or of duty.

The second part of the work is devoted to theoretic navigation and nautical astronomy, and is very complete.

The work, including the tables, occupies 700 pages royal octavo.

REPORT OF THE UNITED STATES LIGHT-HOUSE BOARD. Washington: Government Printing Office.

Within the space of 85 pages there is much matter of interest to engineers who feel no sort of concern about the efficiency of light-houses. The various materials employed in the building both of superstructure and foundation are of course selected with reference to withstanding unusual conflicts with the elements; while the precautions taken to secure stability require a knowledge of engineering methods not called for in ordinary operations, but afford many useful lessons to all branches of the profession.

The pictorial illustrations, mostly tinted views, are exceedingly fine.

TEXT-BOOKS OF SCIENCE: The Strength of Materials and Structures. By JOHN ANDERSON, C.E., LL. D., F.R.S.E. London: Longmans, Green & Co. For sale by Van Nostrand.

The series to which Mr. Anderson's volume belongs promises to be the cheapest and best collection of elementary science books in the language. Every subject is in the hands of a writer having a special knowledge of it. Mr. Anderson first treats of the machinery usually employed in tests, and the strength of materials, including cast and wrought iron, steel, and timber, and then treats as far as possible of the strength of beams and girders, columns, roofs, boilers, guns, etc. Each of these

things might have a volume devoted to it to do it justice, but we don't know of a better first book on the strength of materials in general, or one so well adapted for students who have to depend on self-tuition for their knowledge.

A TREATISE ON THE CONSTRUCTION AND OPERATION OF WOOD-WORKING MACHINES. By J. RICHARDS, Mechanical Engineer. London and New York: E. & F. N. Spon. For sale by Van Nostrand.

Mr. Richards asks for the charitable consideration of this work, as his experience is that of constructor of machines rather than of a writer of books. He need not, however, be afraid of the result of criticism by any one who has had practical experience of machines. His work contains all the information which those who are particularly interested in wood-cutting machines are likely to require. Examples are given of machines by the leading English, French, and American engineers, the drawings are all to scale; and as they are true elevations fully shaded, any readers who may not understand the ordinary sectional drawings will find no difficulty with them. If it had not been for the pressure on our space we had intended to give a detailed account of the book; but no abstract would do justice to the valuable information which Mr. Richards furnishes. All builders who possess machinery of this kind, or who intend to purchase some, ought to study attentively this book.

MISCELLANEOUS.

ON THE BEHAVIOR OF GRANITE.—Some fifteen years ago Mr. H. C. Sorby, of Sheffield, well known for spectroscopic researches, read a paper before the Sheffield Philosophical Society, showing, according to his investigations, that granite, always classed among the igneous or plutonic rocks, contained water in appreciable quantities. This statement created some surprise at the time, but its truth is evidently proved by the unanimous testimony of the writers describing the great fires at Boston, all of whom speak of heaps of disintegrated and splintered granite fragments piled in front of former stately structures, whose builders no doubt thought they worked with enduring material. Constant allusion is also made to blocks of granite being hurled with projectile-like force and explosive noise into the roadways, proving the presence of some powerful internal expansive agency, and Mr. Sorby must be gratified, although in a sad fashion, at this unmistakable evidence as to the soundness of his views on this material. Brick of good quality was the only substance which withstood the fiery ordeal, as of old, and the lesson will not be lost, I ween, in the re-edification of the American Athens. We shall doubless, also, see much concrete used in the new buildings, as I note this material is much employed by French and Italian constructors in their fire-proof houses.

THE ROMAN BATH IN THE STRAND.—It is well worth remembering that, close to the busiest part of modern London, is to be found one of the earliest remains of Roman construction in the metropolis. A hundred yards down Strand lane, close to the Strand Theatre, is to be found a bath constructed some 1,800 years ago, in which the water is now flowing as freshly and as freely as it did at that time. It is capital water, and King's College and other establishments in the neighborhood are supplied from this source, which is constant and unvaried. At a guess the bath is about 14 ft. long and 6 ft. wide, rounded at the west end of it where the water is deepest, say 4 ft., the bottom shelving toward the other end. It is at the deepest end that the spring rises, and the water is so plentiful, probably supplied by the Highgate hills, that it runs away at the rate of about 10 tuns per day. As it runs, however, it passes, before going into the Thames, into an adjacent cold plunge-bath, which thus has a continual change of water for bathers. This latter bath, too, has a story, for it is said to have been formed by the Earl of Essex, Queen Elizabeth's favorite, from whose mansion here a neighboring street is named. The house, however, we are disposed to think, must have been at some distance from this bath.

The sides of the more ancient bath are formed mainly of thin bricks (about 9 in. long and 1¾ in. thick), and mortar. In between the construction of this bath and to-day comes the whole history of England—*Builder*.

THE FUTURE OVERLAND ROUTE TO INDIA.—The first section of the Scutari-Ismidt Railway, which takes its departure at present from the little valley of Haidar Pasha, on the southern side of the Bosphorus, has been opened. If ever we should have an overland route to India, through Asia Minor and the Tigris or Euphrates Valley, this section of the Scutari-Ismidt line will probably be the first portion which travellers will pass over after leaving Stamboul, in Asia Minor. The terminus is about a mile distant from Scutari, and is situated at the embouchure of the little valley of Haidar Pasha. On leaving the terminus the line makes a sharp curve towards the south, skirting along the shores of the Sea of Marmora. The ballasting and straitening are only partially done, and to all appearance there cannot have been more than one "lifting." Most of the banks have not settled yet, and after a few good rains a considerable filling up will, no doubt, be required. The culverts, too, are few in number, and their openings will certainly be found too narrow. The masonry is of a very indifferent quality, and as there is no coping a few autumn rains will melt much of the work away. The two little stations along the line are built of wood, but are quite sufficient for present requirements. Sidings, turn-tables, and other such accessories are yet wanting. The rolling stock, engines, and carriages are of Belgian make, and of inferior workmanship. It is expected that the whole of the line to Ismidt—about 90 miles in length—will be finished by the end of February. The contemplated extension to Kuytayah and Angora—five times as long as this first section—has been only lately abandoned, after the whole of the details of the concession to M. Pressel, the Government engineer, had been settled.

NEW HAVEN, Ct., is to have a splendid new railroad depot 600 ft. long, with spacious platforms and elegantly fitted waiting-rooms and offices. They needed it bad enough. Those who have ever explored the subterranean depth of the old one will now rejoice and be glad over the prospect.